

Muscatatuck National Wildlife Refuge

Water Resource Inventory and Assessment (WRIA) Summary Report

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The mission of the U.S. Fish & Wildlife Service is working with others to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people.

The mission of the National Wildlife Refuge System is to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.

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Author's Note:

There are embedded links throughout this document within the table of contents and indicated by underlined text. A database of the presented data, additional data, documents and the referenced studies will be available as part of a digital document library housed on the Environmental Conservation Online System (ECOS). Geospatial data layers were obtained from the Muscatatuck National Wildlife Refuge Staff, the National Hydrography Dataset from USGS's National Map, the University of Indiana Portal, and the Indiana Department of Environmental Management (IDEM).

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Chapter 1: Executive Summary

The Water Resource Inventory and Assessment (WRIA) is a reconnaissance-level effort, which provides:

- Descriptions of topography and natural setting information
- Historic, current, and projected climate information, including hydroclimate trends
- An inventory of surface water and groundwater resource features
- An inventory of relevant infrastructure and water control structures
- Summaries of historical and current water resource monitoring, including descriptions of datasets for applicable monitoring sites
- Brief water quality assessments for relevant water resources
- A summary of state water laws
- A compilation of main findings and recommendations for the future

The WRIA provides inventories and assessments of water rights, water quantity, water quality, water management, climate, and other water resource issues for each Refuge. The long-term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date, accurate data on Refuge System water quantity and quality in order to acquire, manage, and protect adequate supplies of water. Achieving a greater understanding of existing information related to Refuge water resources will help identify potential threats to those resources and provide a basis for recommendations to field and Regional Office staff. Through an examination of previous patterns of temperature and precipitation, and an evaluation of forward-looking climate models, the U.S. Fish and Wildlife Service (USFWS) aims to address the effects of global climate change and the potential implications on habitat and wildlife management goals for a specific Refuge.

WRIAs have been recognized as an important part of the NWRS Inventory and Monitoring (I&M) and are identified as a need by the Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change (USFWS 2010a, b). Inventory and Monitoring is one element of the U.S. Fish and Wildlife Service's climate change strategic plan to address the potential changes and challenges associated with conserving fish, wildlife and their habitats (USFWS 2011). Water Resource Inventory and Assessments have been developed by a national team comprised of U.S. Fish and Wildlife Service water resource professionals, environmental contaminants Biologists, and other Service employees.

The WRIA summary narrative supplements existing and scheduled planning documents, by describing current hydrologic related information and providing an assessment of water resource needs and issues of concern. The WRIA will be a useful tool for Refuge management and future assessments, such as a hydro-geomorphic analysis (HGM) and, and can be utilized as a planning tool for the Comprehensive Conservation Plan (CCP), Habitat Management Plan (HMP) and Inventory & Monitoring Plan (IMP). The CCP (USFWS, 2009) and HMP (USFWS, 2011) are both complete for Muscatatuck National Wildlife Refuge (MNWR). Much of the information within these plans relate to water resources and are reiterated in the WRIA summary narrative.

This Water Resource Inventory and Assessment (WRIA) Summary Report for MNWR describes current hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations regarding Refuge water resources. As part of the WRIA effort for this Refuge, water resources staff in the Division of Natural Resources and Conservation Planning (DNRCP) received review comments and edits from Josh Eash, James Stack, and Refuge Manager Alejandro Galvan.

This Summary Report synthesizes a compilation of water resource data contained in the national interactive online WRIA database (<https://ecos.fws.gov/wria/>). The information contained within this report and supporting documents will be entered into the national database for storage, online access, and consistency with future WRIAs. The database will facilitate the evaluation of water resources between regions and nationally. This report and the database are intended to be a reference for ongoing water resource management and strategy development. This is not meant to be an exhaustive nor a historical summary of water management activities at MNWR refuge.

The following two sections describe in detail the key findings and recommendations from this assessment. Relating to this, the online WRIA database list threats and needs for the refuge. Those threats and needs are compiled in a table in Appendix A.

1.1 Findings

- Richart Lake is the primary water source for the managed moist soil units M1 through M4. This lake is only 90 acres in size and has a small watershed. Water flows from Richart lake to M1, then into M2, into M3, and finally into M4. Richart Lake is fed only by ephemeral streams, and there can be insufficient water during dry years to fill M3 and M4. (i.e. Filling M4 can take weeks). This indicates that the current management strategy of the refuge may not be very resilient to climate variations.
- Mutton and Storm Creeks have extensive beaver activity. Removing dams is labor intensive and dangerous activity for refuge staff. In the forested areas along these creeks, beaver activity will likely be a persistent and perennial occurrence. Even if alternative methods of beaver dam removal were feasible (i.e. use of explosives, or a floating aquatic excavator), beaver dam removal would still be burdensome to refuge staff time. Also, previous management actions and beaver activity caused sustained high water levels in Moss Lake from 1992 to 2008, which has resulted in large areas of dead timber throughout the Moss Lake and Mutton Creek flood plain area. This dead timber is the source of substantial amounts of debris in Mutton Creek causing log jams, which further contribute to the impediment of flow.
- The impediments to flow along Storm and Mutton Creek ditches from beaver activity and aggradations has likely caused more frequent overbank flooding, which could damage current infrastructure. This is especially the case along Storm Creek where management units are adjacent to the Storm Creek ditch and restrict the natural meandering of the stream channel. Impediments to flow has resulted in persistent flooding in some areas of the refuge such as the Muscatatuck Seep Spring Research Natural Area, which is a rare ecological habitat in the state of Indiana, as well as moist soil unit M6 resulting in increased invasive cattails in M6.
- For an upstream gauging location on the Vernon Fork Muscatatuck River as well as nearby Hydro-Climatic Data Network (HCDN) stream gauging locations, the average annual (although not the annual peak) discharge has shown an increasing trend since mid-century. This trend is correlated with a significantly increasing trend in annual precipitation and in the frequency of precipitation events greater than 1 inch from 1900–2017. For other creeks entering the MNWR, peak discharge and flashiness has likely further increased compared to the pre-settlement levels due to urbanization and tiling in the watershed. Altogether, this indicates an increase in the amount of water entering the refuge.
- The surface waters flowing into the MNWR receive high sediment loads, which has resulted in siltation and aggradation along Storm Creek and Mutton Creek ditches. Aggradation could further inhibit flow through these ditches, reducing their ability to convey water as designed. High sediment loads could also cause aggradation in impoundments and management units on the MNWR.
- The refuge also receives high nutrient loads, with total phosphorus concentration often exceeding the EPA recommendations for Eco-Region VI in the lakes and streams of the refuge. This is a result of non-point source agricultural runoff and point source pollution from urban runoff and potentially from sewage outfall in upstream residential developments.

- High nutrient levels in Richart, Stanfield, and Moss Lake cause water quality issues in these lakes including algal blooms in Richart and Stanfield lakes, and low dissolved oxygen, especially in Moss Lake. Harmful algal blooms can produce toxic chemicals, which can be a potential threat to pets and wildlife. Low dissolved oxygen levels can also result in fish kills in lakes, although fish kills have not been observed in Richart and Stanfield Lake as yet.
- Mutton Creek within the MNWR boundary is listed as a 303(d) impaired water body for E. Coli by the Indiana Department of Environmental Management (IDEM). This may suggest potential sewage discharge into this watershed, possibly from sewerage overflow during storm events in upstream residential developments on Mutton Creek.
- All of the source water entering MNWR is listed as 303(d) impaired by IDEM. The degree to which source waters are impaired points to potential chronic water quality issues across the refuge, potentially exacerbated by impounding these waters.

1.2 Recommendations

The WRIA provides a collection of recommendations related to the primary findings outlined above. Alternative opportunities to act on current or future threats may exist, and each water resource concern and recommendation should be thoroughly assessed prior to the implementation of management actions.

- Working together with the regional water resources branch, the hydrology of the Richart Lake and the upstream watershed could be assessed to understand best management practices of this lake under various meteorological scenarios, to have sufficient water for moist soil units under dry conditions. In particular, the available volume of water in Richart Lake and other lakes could be determined via bathymetric surveys and compared to the volume of water required by the moist soil units and the volume of inputs from the intermittent streams in the watershed.
- Assessing the functioning of the current infrastructure and planning any potential future changes to refuge infrastructure or management requires a baseline understanding of the system hydrology. Working together with the regional water resources branch, the timing and magnitude of discharge through Storm Creek and Mutton Creek could be measured in the field and compared to the conveyance capacity of the current infrastructure.
- The groundwater and hydrology of the Seep Spring Research and Natural Area should be monitored to assess the hydrological vulnerability of this rare ecological area. Also, the connection between the hydrology in this area and other hydrological features such as Mutton Creek should be investigated to reduce flooding issues in this area.
- Issues with flooding and associated damage, aging ditches and infrastructure, beaver dams, and sedimentation can interfere with the proper management of units on the refuge. Addressing these issues will likely require continued maintenance (e.g. beaver dam removal, flood damage repairs, dredging, etc.) and/or increased infrastructure (e.g. improved access roads along the creek channels or equipment like an aquatic excavator, enhanced levees along active management units, etc.). Alternatively, there could be a focus on restoring the natural hydrological functioning on the refuge, which would include restoring natural stream meanders, deconstructing levees to improve flood plain connectivity, constructing low water crossings at roads upstream of Moss Lake, etc. This approach has already been taken in a number of areas of the refuge including the southern management units, and at Mini Marsh, which have been allowed to revert to more natural hydrological fluctuations. With this approach, beaver activity may be less of an issue, and if well designed, sediment balance, flood issues and maintenance costs would be improved. Regional water resource branch staff and other experts could be enlisted to explore options.
- In order to understand and mitigate the high sediment loads received by the refuge, initial investigation is needed to better characterize the sediment loads, source, and amount of legacy sediment in the refuge water bodies. As part of this investigation, the sedimentation rate in Richard and Stanfield Lakes could be characterized by repeating bathymetry 10-20 years after the initial surveys were done in 2009.
- There is a need to characterize issues with the potential point source sewage overflows upstream of the refuge. By working together with residential developments, landowners, and municipalities, issues with upstream point source pollutants could be identified and documented. Then, through education and collaboration, these issues could then be addressed.

- By working with local landowners, and other organizations like local soil and water conservation districts, and the NRCS, water quality issues including sediment loads and nutrients within the source watersheds of MNWR could be discussed and improved. In this case, reaching out to the local landowners and others may be feasible because Storm Creek and Mutton Creek have a relatively small source watersheds. Further, recreational opportunities provided by the refuge in close proximity to Seymore, IN and other towns may help encourage a local sense of ownership for water quality issues of the source watersheds.

Chapter 2: Introduction

As described in the 2011 Habitat Management Plan (HMP), the Muscatatuck National Wildlife Refuge (MNWR) is located in south-central Indiana, three miles east of Seymour, IN, approximately half way between Indianapolis to the north and Louisville, KY to the south. The Refuge was established in 1966 by the Migratory Bird Conservation Commission and today consists of 7,724 acres in Jackson and Jennings counties, as well as the 78-acre Rustle Unit located north of Bloomington in Monroe County, IN. The Refuge also administers 8 conservation easements totaling 105.5 acres in four Indiana counties (USFWS, 2011).

The refuge supports a high diversity of wildlife due in a large part to the diversity of habitats, with over 280 species of bird including 121 breeding species of birds, 40 species of reptiles, 38 species of mammals, and 85 species of fish that have been recorded on the refuge. The Refuge is well known for the spring and summer migration of songbirds in May, and was listed as a "Continentially Important" bird area in 1998. Several state listed reptiles and amphibians have been documented on the refuge including the copperbelly watersnake, Kirtland's snake, and the four-toed salamander, and state listed fish include the bigeye chub, northern studfish, and the eastern sand darter. The refuge is also home to the federally endangered Indiana bat and state endangered evening bat (USFWS, 2011).

Wetlands cover 69 percent of the Refuge and much of this land floods annually. The majority of wetland habitat is bottomland hardwood forest and managed impoundments that include moist soil units, brood marshes, green tree reservoirs, and Stanfield, Moss and Richart Lakes. Most of the wetland infrastructure was built in 1979–1982 with Bicentennial Land Heritage Program funds. The Refuge also has over 70 other small ponds and wetland areas including several groundwater seeps. The Muscatatuck Seep Spring Research Natural Area is an acid seep spring that has only been documented in seven other locations in Indiana, one of which was destroyed, making it extremely rare in the state (USFWS, 2011).

As described in the 2009 Comprehensive Conservation Plan (CCP), the Refuge lies within a flat, relatively well drained portion of the Wabash River Basin. Water flows away from the Refuge down the Vernon Fork of the Muscatatuck River, into the Muscatatuck River, the White River, and on to the Wabash River. Three small streams, Sandy Branch, Mutton Creek, and Storm Creek, flow through the Refuge and enter the Vernon Fork soon after leaving the Refuge. These streams have a combined watershed area upstream of the refuge that covers 30,100 acres, including the eastern portion of Seymour, IN. The annual floodplain of the Vernon Fork extends 2,000 to 3,500 feet into the Refuge along its southern border. Annual floods from this river inundate approximately 2,700 acres of the Refuge (USFWS, 2009).

Chapter 3: Natural Setting

The natural setting section describes the abiotic resources associated with the Refuge, including relevant watershed boundaries, topography, and climate. These underlying, non-living components of an ecosystem provide the context on which water resources are constructed and managed. Many of these elements are also described in 2011 Habitat Management Plan (HMP) and the 2009 Comprehensive Conservation Plan (CCP).

3.1 Region of Hydrologic Influence (RHI)

Hydrologic information can be described in the context of MNWR designated Region of Hydrologic Influence (RHI), which is the relevant region for the collection of water quality and quantity information. For the main unit at the MNWR, the RHI was designated to include all of the upstream watershed including the Vernon Fork watershed and the Mutton Creek and Storm Creek watersheds (Figure 3-1). Hydrologic Unit Codes (HUCs) designate watersheds of various sizes and often represent the initial aggregate level of water quality and quantity information available from a variety of agencies. HUC boundary datasets can be obtained from <https://gdg.sc.egov.usda.gov/GDGOrder.aspx?order=iMapOrder>. The RHI of the MNRW main unit is located entirely in the Muscatatuck River watershed (HUC8 05120207) and the Vernon Fork Muscatatuck River sub-watershed (HUC10 0512020703, 0512020704, and 0512020707). The refuge boundary is located entirely within three HUC12 watersheds (051202070705, 051202070704, 051202070703). The Restle Unit of the MNWR is located in the HUC12 watershed (051202020106) within the larger Lower White river watershed (HUC8 05120202). More information about drainage boundaries can be found at this link to USGS StreamStats <https://water.usgs.gov/osw/streamstats/>.

Muscatatuck NWR Region of Hydrologic Influence

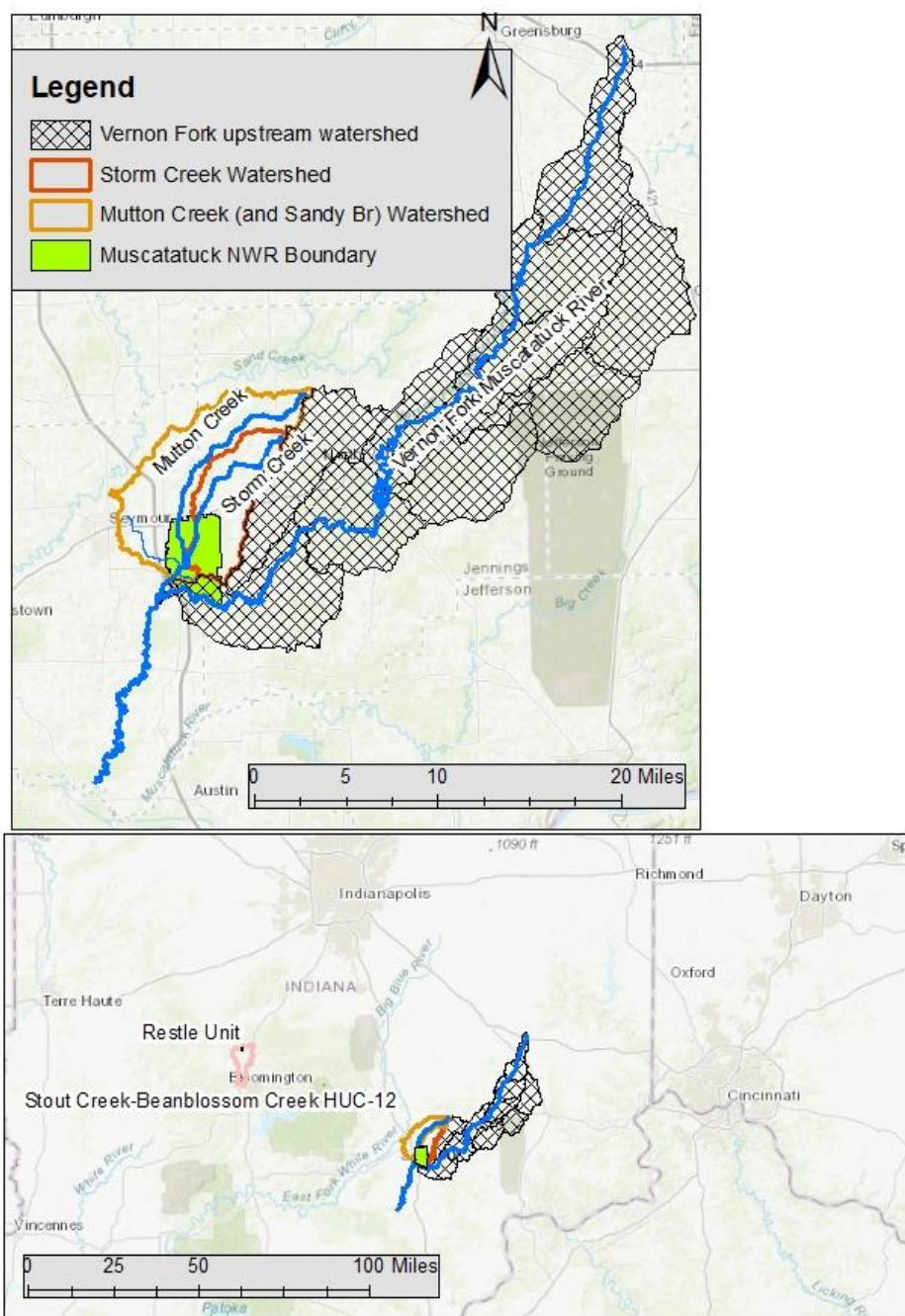


Figure 3-1. Region of hydrologic influence (RHI) for the Muscatatuck NWR

Table 3-1. Areas of watersheds and total area of the RHI for MNWR. Note: The actual RHI for the Restle units is much smaller than the total HUC12 area listed here.

Main Unit.

Watershed Name	Area (sq. mi.)
Total RHI area	357.4
Mutton Creek (and Sand Creek) HUC-12	41.1
Storm creek HUC-12	23.3
Vernon Fork Muscatatuck River upstream	293.1

Restle Unit

Watershed Name	Area (sq. mi.)
Stout Creek-Beanblossom Creek HUC-12	24.3

3.2 Topography

High resolution (1-meter) bare-earth LiDAR data (NAVD88) is currently available for MNWR refuge. It was processed by Vince Carpeder, collected in 2011 by the Indiana Statewide Imagery and LiDAR Program, and downloaded from the University of Indiana Portal and processed by Vince Capeder. Topographic maps are shown below (Figure 3-2).

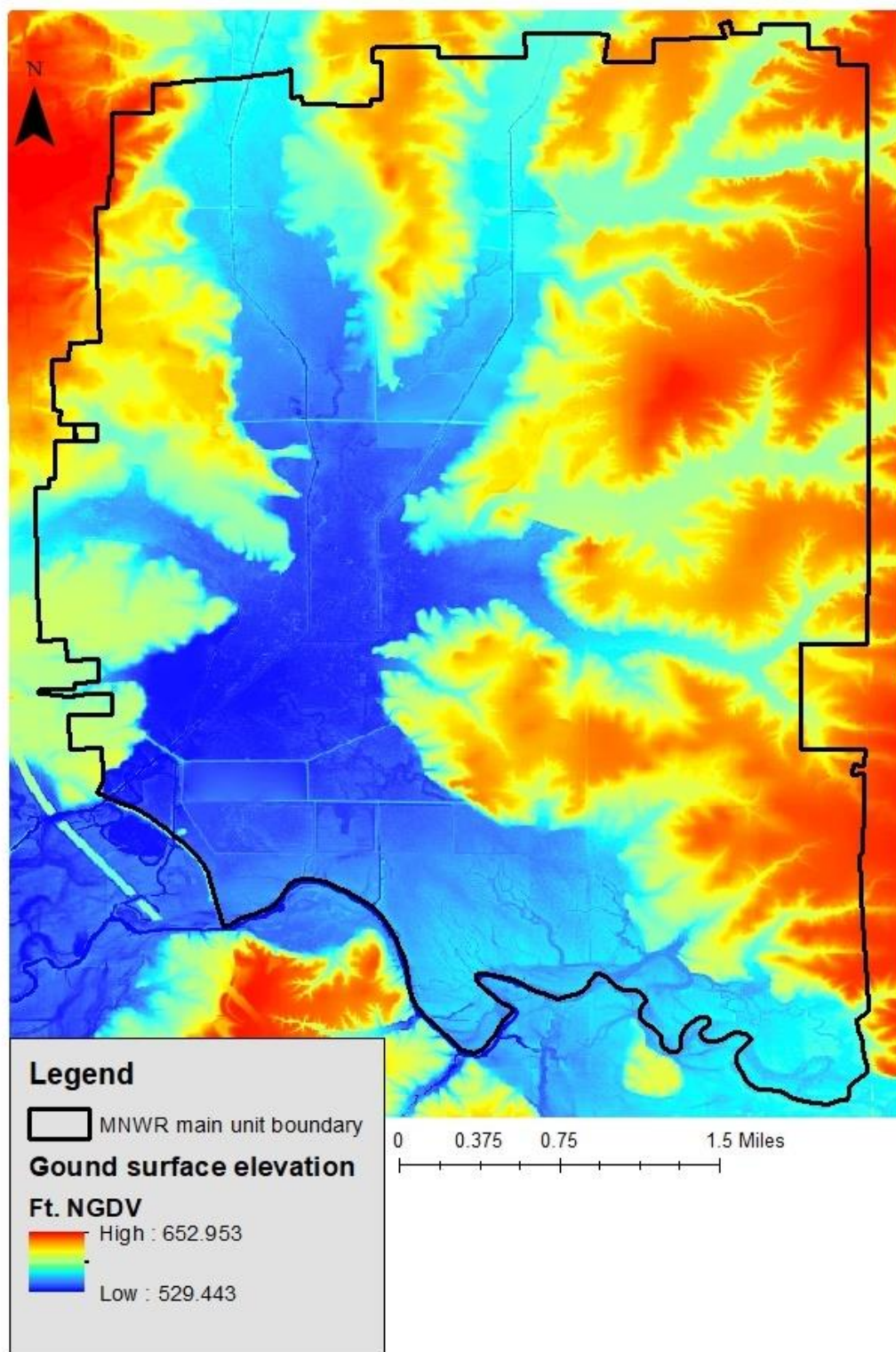


Figure 3-2. Topographic elevation throughout the main unit of the MNWR in ft NGVD.

3.3 Long Term Climate Trends

The WRIA provides a preliminary broad-based analysis of trends and patterns in precipitation and temperature. Climate is defined here as the typical precipitation and temperature conditions for a given location over years or decades. These types of trends and patterns affect groundwater levels, river runoff, and flooding regularity and extent. This section evaluates MNWR's current and historical climate patterns by:

- Discussing the current climate and changes already experienced in the region
- Briefly summarizing projections for the future from selected models
- Analyzing a U.S. Historical Climatology Network (USHCN) dataset

Historical climate conditions and projected changes

The climate of the southern half of Indiana and the region surrounding MNWR is characterized as humid subtropical, with hot and humid summers and mild to cool winters. This region receives more precipitation than the northern half of Indiana with its humid continental climate. The National Climatic Data Center's describes the "normal" or the 30-year average climate of Indiana as follows (Arguez et. Al. 2012):

"Indiana has an invigorating climate with strongly marked seasons. Winters are often cold, sometimes bitterly so. The transition from cold to hot weather can produce an active spring with thunderstorms and tornadoes. Oppressive humidity and high temperatures arrive in summer. Autumn is favored by many residents as a pleasant time of the year with lower humidity than the other seasons, and mostly sunny skies."

In southern Indiana, the average high temperatures (Fahrenheit) in the summer are in the 80s with average lows in the 60s. Winter highs are generally in the 30s with lows in the teens. Temperature extremes range from the minus 30s to highs over 110 degrees. The average annual precipitation in southern Indian is about 47 inches, with May being the wettest month with the average rainfall between 4 and 5 inches and winter months being the driest with typically less than 3 inches of precipitation each month. The average annual rainfall for the Refuge is 39.9 inches, with over 50 percent normally falling during the months of April through August. There is an average of 6 months without frost each year.

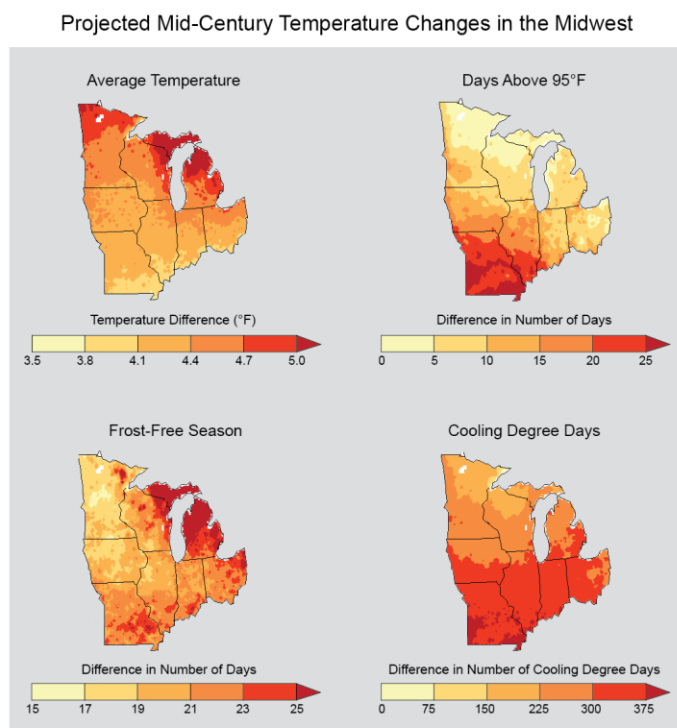
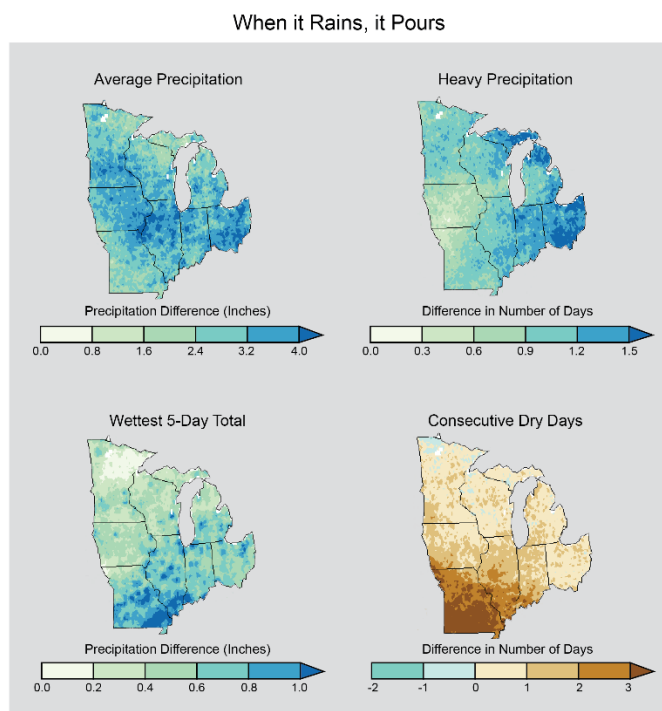


Figure 3-3. Projected changes in climate across the Midwest by mid-century (NOAA NCDC / CICS-NC, 2014)

Kunkel et al. 2013). The Midwest has experienced an increase in runoff, with expectations of more intense flood conditions (Johnson et al. 2015, USEPA, 2016) and more frequent short-term droughts (UCS, 2009) in the future.

The nation as a whole has experienced a 1.3-1.9 degree Fahrenheit increase in average temperatures since 1895, and can expect a 2-4 degree increase over the next century (Melilo et al. 2014), although this change is not uniform over all regions of the country or over time (Winkler et al. 2012, Melilo et al. 2014). Indiana specifically has warmed about 1 degree Fahrenheit over the last century (USEPA, 2016). A 2004 study showed that areas in the central United States (including parts of Indiana) are experiencing a local minimum of warming compared to the rest of the nation, due to the interaction between increased precipitation, soil moisture, and evapotranspiration (Pan et al. 2004, Pryor et al. 2013). This results in reduced warming from July-October, and similar or increased warming during the cold-season (Pan et al. 2004). The Midwest has experienced an increase from historic times in the average frost free season by 9 days (Melilo et al. 2014), and this is projected to increase to 14 days by mid-century and 28 days by the end of the current century (Pryor et al. 2013). Despite the slower rate of warming, Southeastern Indiana can expect a 5-15 day increase in the number of >95 degree days by mid-century, and an increase of average temperature by about 3.8 to 4.4 degrees Fahrenheit (Pryor et al. 2014) (Figure 3-3), and by the end of the century, every summer in Indiana will be as hot as or hotter than 1983 (Indiana's hottest summer of the last half century) if our heat-trapping emissions continue to increase at the current rates (UCS, 2009). Several reports indicate that the Midwest is experiencing heavy precipitation events that are currently much more frequent and intense in the region than they were a century ago (Kunkel et al. 2003, Winkler et al. 2012,

USHCN Dataset

Data was obtained from a site from the U.S. Historical Climatology Network ([USHCN]; <http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn.html>; Menne et al. 2012). The USHCN is a network of sites listed by the National Weather Service, which maintains standards in quality and continuity of data collection. The near-by USHCN station used for climate trend analysis is Greensburg, IN, USC00123547. It is located 29 miles to the north east of MNWR, and has an elevation of 286 feet while the Refuge complex has elevations in the range of 530–650 feet. Years with more than two missing months of data were dropped from the analysis to avoid erroneous annual statistics.

- The Greensburg, IN USHCN weather station (1900-2017) showed a mean annual water year precipitation of 40.3 inches, with the wettest years on record (>52 inches of precipitation) occurring in 1950, 1957, 1974, 1990, 2006, 2008, and 2011, while particularly dry years (<29 inches of precipitation) occurred in 1900, 1908, 1914, 1923, 1930, 1934, and 1953 (Figure 3-8). The highest total monthly rainfall typically occurs April through June (Figure 3-4). The average cool season precipitation (October to March) was 16.7 inches.
- There is evidence of an increase in both the average annual precipitation as well as the magnitude of heavy rain events since the beginning of the data record (1900) (Figure 3-7). There has been an increase in the overall annual precipitation over time ($p < 0.001$, median = 39.9) as well as increases in the number of rainfalls 0.25 inches or greater ($p < 0.001$) in a 24-hour period. There is a trending significant linear relationship between the number of days in a year with 1-inch or greater rainfall from 1900-2017 ($p = 0.032$, median = 9.3 days) (Table 3-2). Average cool season precipitation (October to March) has shown a statistically significant increase over time ($p < 0.001$) (Figure 3-9).
- The trend for increased extreme precipitation is further explored in Table 3-3. Rainfalls of 0.01 inches or greater in a day have increased in the past 30 years compared to the historic record. Overall days with rainfall (< 1") have shown a 5% or less of an increase in recurrence, where as rainfalls greater than 1" have shown a large increase in recurrence (between 16% and 60%).
- Average monthly temperatures are typically highest in July (71.9 F) and coolest in January (25.6 F) (Figure 3-5). Average annual mean temperatures have not shown a statistical trend, however, average fall temperatures have shown a slight decrease ($p = 0.096$, median = 55.3) (Figure 3-8).
- Average growing length season has shown a mildly statistically significant increase over the period of record (1896-2018) (median = 179, $p = 0.08$) (Figure 3-6). Most of the past 30 years have experienced growing seasons longer than the average. Indiana as a whole has shown a 13.45 day increase from the average 1895-2016 growing season length, with the majority of the increase occurring in the spring (8.13 days earlier) (Kunkel 2017).

Table 3-2. Statistically significant climate trends for 1900-2017, Station No. 00123547, Greensburg, IN.

Kendall's Tau Non-Parametric Monotonic Trend Test

Dependent Variable	p-value	slope	median
<i>Annual Average Precipitation</i>	< 0.001	(+)	39.9
<i>Annual Maximum Temperature</i>	< 0.001	(-)	63.4
<i>Summer Minimum Temperature</i>	0.0189	(+)	62.3
<i>Cool Season Average Precipitation</i>	< 0.001	(+)	NA
<i>Cool Season Average Maximum Temp</i>	0.049	(-)	NA
<i>Annual # Days With Precipitation > 1"</i>	0.032	(+)	9.87
<i>Length of Growing Season</i>	0.08	(+)	179

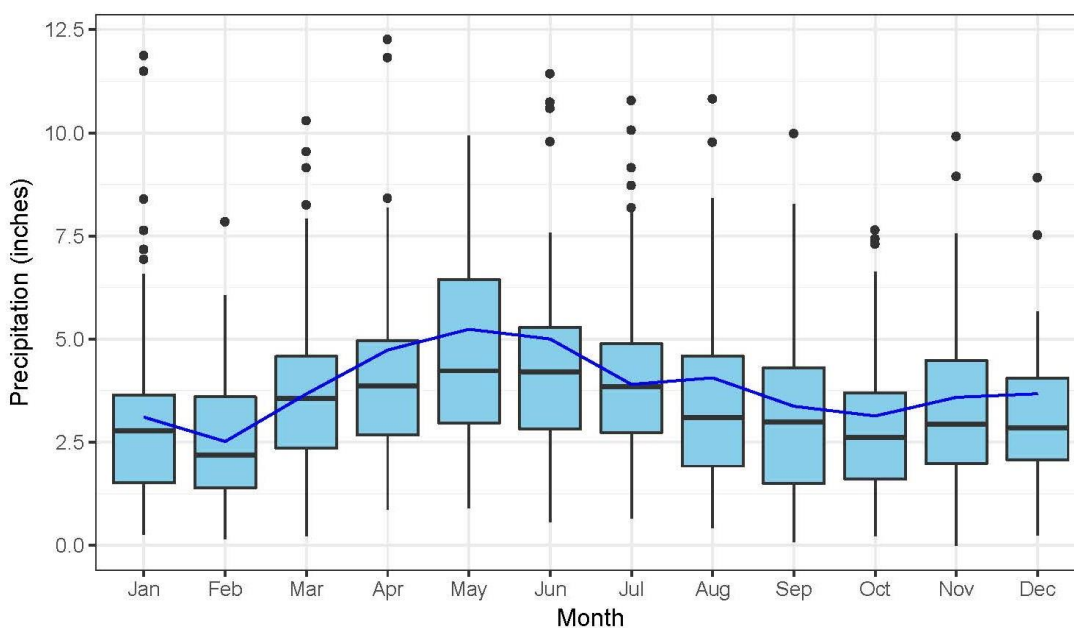


Figure 3-4. Average total monthly precipitation (1986-2015) for USHCN station in Greensburg, IN, USC00123547.

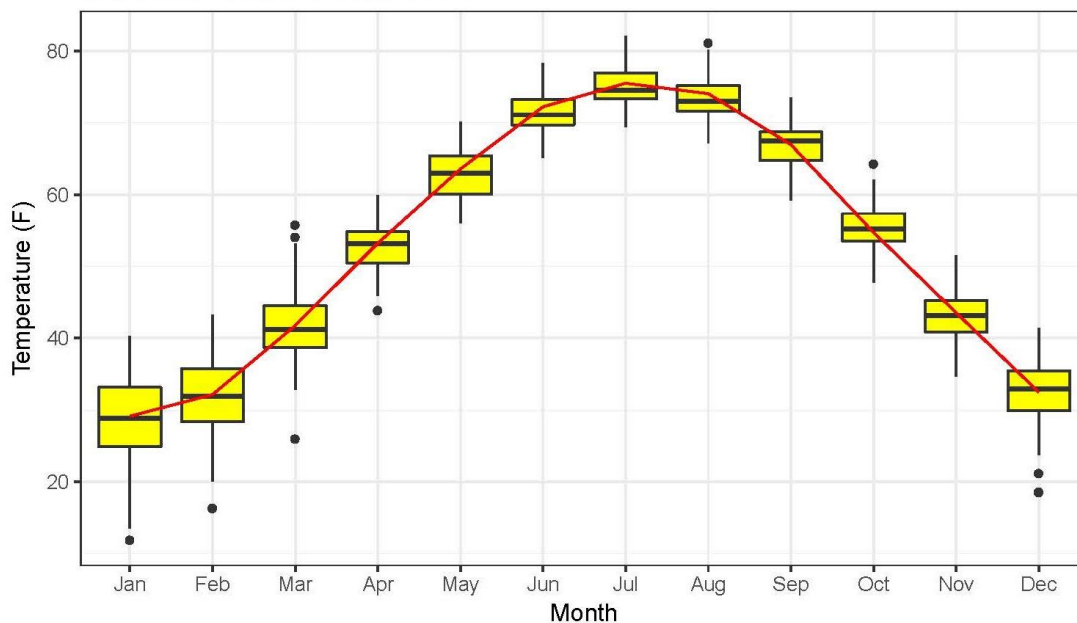


Figure 3-5. Average monthly temperatures (1986-2015), for USHCN station in Greensburg, IN, USC00123547.

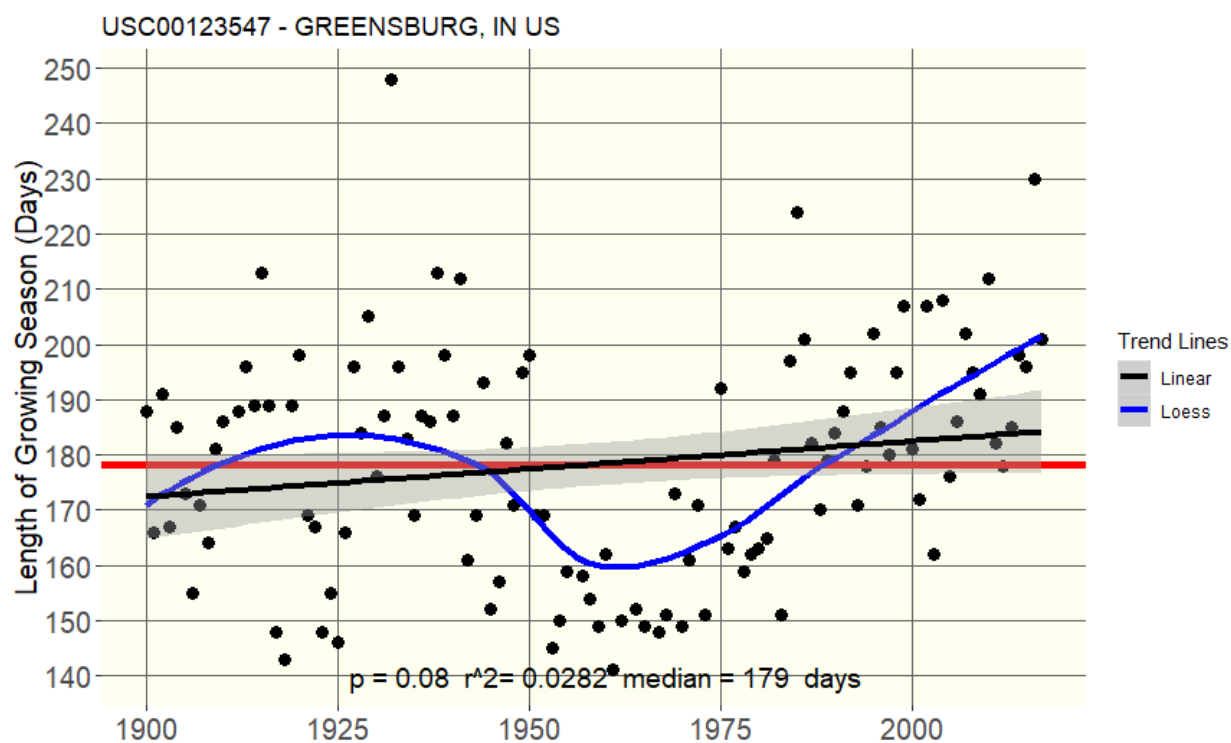
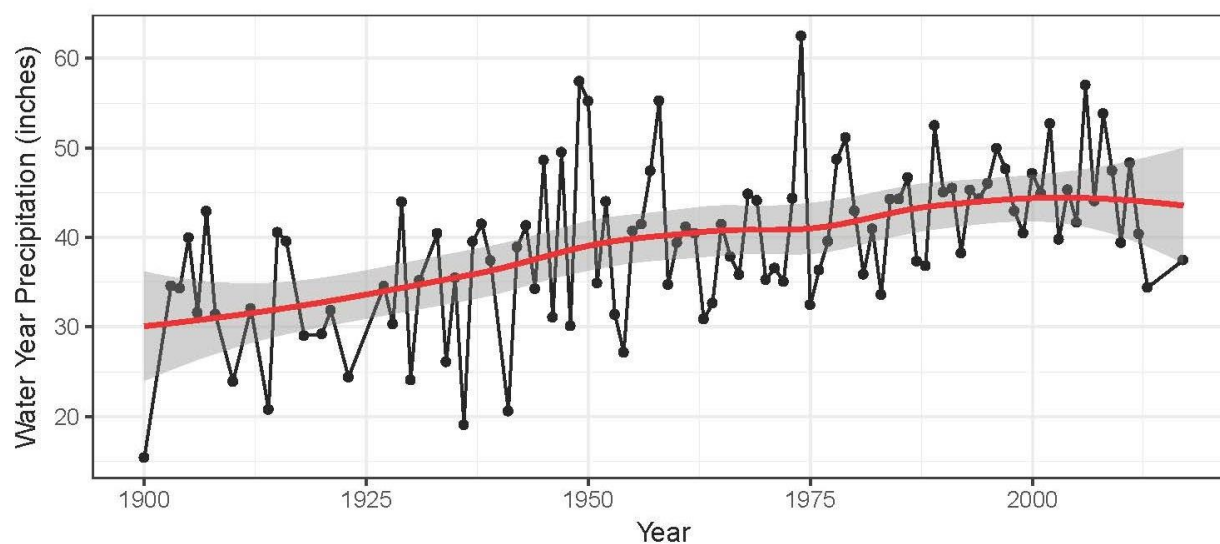


Figure 3-6. Length of growing season (last freeze in spring to first freeze in fall) for Greensburg, IN 1896-2018. Red line is average growing season length (179 days), black line is a linear regression

Table 3-3. Cumulative frequency of daily rainfall of various magnitudes for Greensburg, IN.

Inches of rain in a day equaled or exceeded	Avg. Number of day/year (1900-1984)	Avg. Number of days/year (1985-2017)	Percent Change
5	0	0.06	+100%
4	0.07	0.15	+52%
3	0.27	0.32	+16%
2	1.3	1.85	+30%
1	4.5	11.2	+60%
0.5	28.9	30.3	+4.5%
0.25	51.2	52.4	+2.3%
0.1	77.7	79.8	+2.6%
0.05	92.2	94.7	+2.6%
0.01	111	117	+4.6%

**Figure 3-7. Water year annual precipitation (inches) (1900-2017), Station No. 00123547, Greensburg, IN. The red line represents a polynomial smoothing of the annual data.**

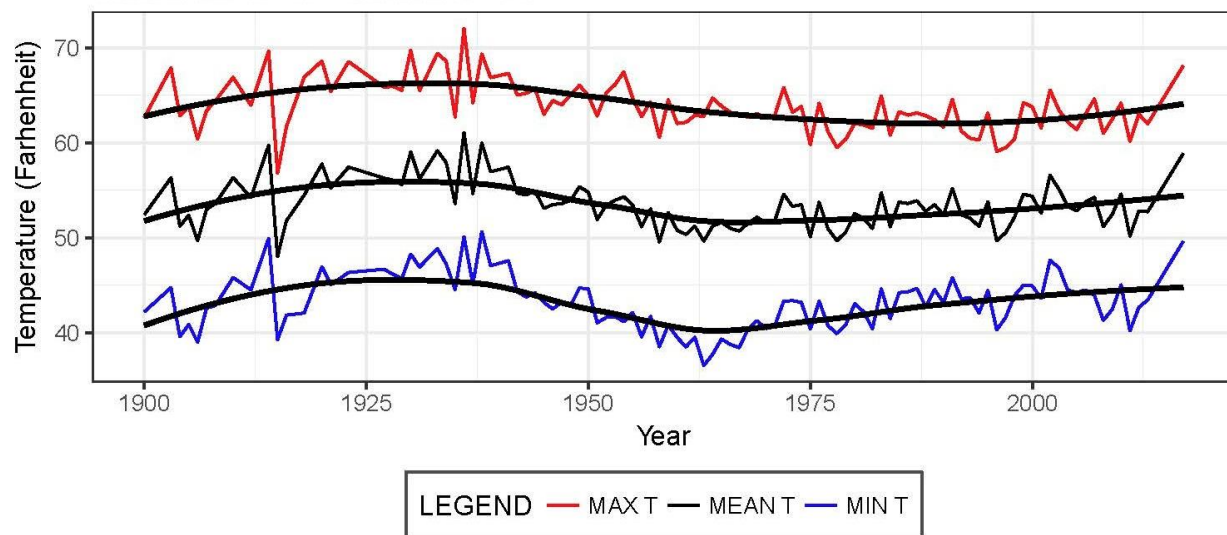


Figure 3-8. Water year average maximum, minimum, and mean temperatures (Fahrenheit) (1900-2017), Station No. 00123547, Greensburg, IN.

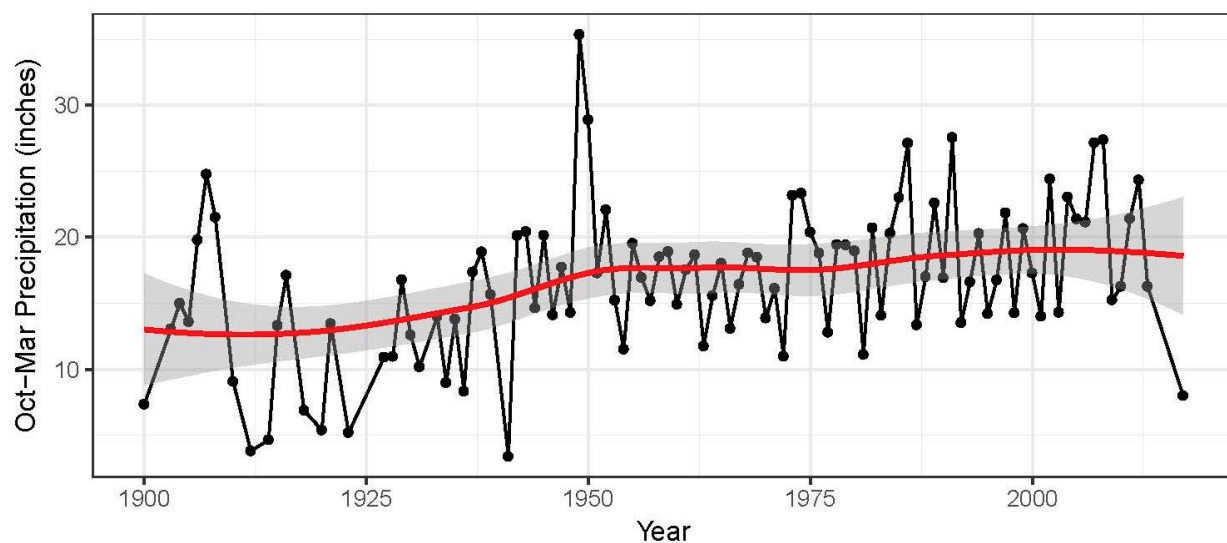


Figure 3-9. Water year cool season precipitation (inches) (1900-2017), Station No. 00123547, Greensburg, IN. The red line represents a polynomial smoothing of the annual data.

Chapter 4: Water Resource Features

4.1 Management Units

A thorough description of the management units at the MNWR can be found in the habitat management plan (HMP) (USWF, 2011). A map of the main management units is shown in (Figure 4-1). Information on the main management units in the MNWR including elevation data and acreage was taken from the 2011 HMP and is summarized in Table 4-1.

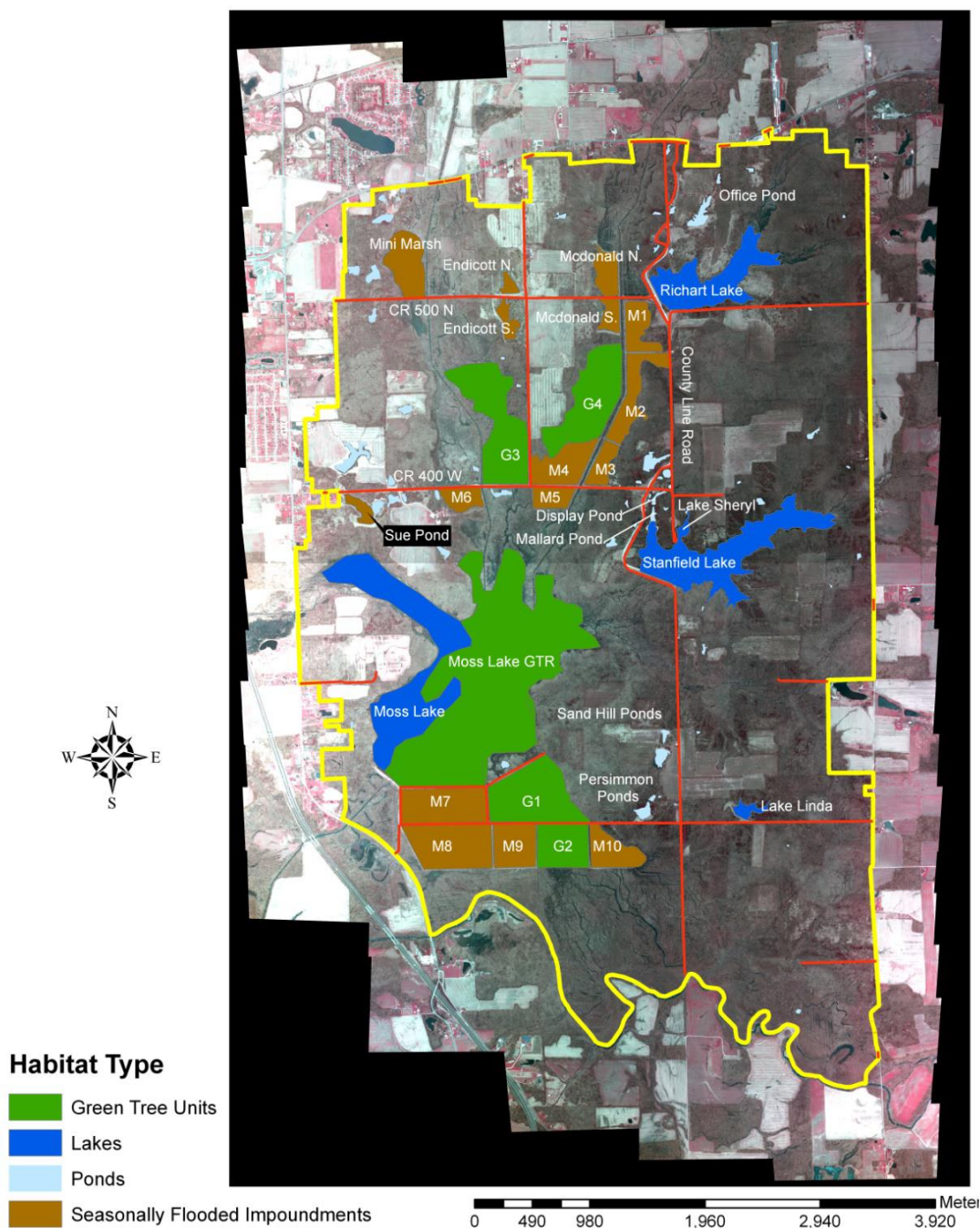


Figure 4-1. Map of management units at the MNWR, from the HMP published in 2011.

Table 4-1. Primary management units in the MNWR, with acreage and elevations data summarized from the HMP published in 2011. Note that some changes in infrastructure have occurred since 2011. These changes are described in the notes below and in main body of the text.

Management Unit	Acreage	WCS outlet floor (Ft MSL)	Maximum pool elevation and/or maximum WCS elevation (Ft MSL)
M1	22	544.11	549.5
M2	20	541.07	547.5
M3	17	539.08	545.46
M4	37	539.08	545.44
M5	13	539.06	543.92
M6	14	541.86	544.34
M7	52	534.36	543
M8	64	536.53 ¹	543.28 ¹
M9	32	539.26 ¹	543.78 ¹
M10	25	550.5 ¹	544.37 ¹
McDon N	20	547.82	553.32
McDon S	12	--	551.57
Sue pond	13		556
Richart Lake	90	547.7	55.5
Stanfield Lake	125	--	559.1
Moss Lake	Variable: 90-1000	537.82	546.1 ²
G1	76	537.51 ¹	545.41 ¹
G2	40	539.9 ¹	543.76 ¹
G3	92	--	544
G4	32	--	--
Endicott marsh N	8	551.46	--
Endicott Marsh S	4	545.03	--
Mini Marsh	36	-- 1	1

Notes:

- 1. Management units no longer being managed, WCS has been removed. Cuts have been put into the dams so maximum pool elevation is now lower than this value.**
- 2. In 2012, the Moss Lake Dam was cut down to a specified elevation of 540.0 ft MSL.**

A number of changes to the management units have occurred since the HMP was published in 2011. In particular, the southern management units, M8, M9, G2, M10, and G1 are no longer actively managed and cuts have been put into the levees of these management units, such that they can flood and dry according to the natural fluctuations of the Vernon Fork Muscatatuck River (communication with refuge staff). Mini Marsh is also no longer actively being managed and has been allowed to slowly revert to a natural flood plain/meander of the Mutton Creek. Cuts have been placed in the levee of Mini Marsh. Also, a large cut was put into the southeast portion of the Moss Lake dam in 2012, as described more fully below. The refuge is waiting for

low water periods to install a water control structure (WCS) on McDonald Marsh S; none is there currently.

Frequent flooding has occurred in M5 and M6 from Storm and Mutton Creek, respectively. The other management units along Storm Creek (M1–M4) flood less frequently. The water level in M6 is difficult to draw down, which has resulted in expansion of invasive hybrid and narrow leaved cattail. Flooding in M5 from Storm Creek has resulted in issues with erosion around the WCS.

High water levels were maintained in Moss Lake from 1992 to 2008 (Figure 4-2), which “resulted in the loss of approximately 700 acres of mature bottomland forest” (USFWS, 2011) despite stated management goals to maintain bottomland forest as a green tree area. The management strategy at Moss Lake area was changed after 2009 to manage the water at a lower level. In summer 2012, a large spillway was installed in the Moss Lake dam. This spillway was specified at an elevation of 540.0 ft MSL; this elevation was based on waterfowl surveys in Moss Lake from 2009–2011. In recent years, Moss Lake has been considered “good duck habitat” (communication with refuge staff). The spillway in the Moss Lake dam has successfully reduced upstream flooding issues on Storm and Mutton Creek, and has allowed water levels in Moss Lake to subside much more quickly following flood events (refuge staff communication). Still, much of Moss lake area continues to have standing water throughout the year, and it is unknown if the regeneration of flood plain tree species has occurred.

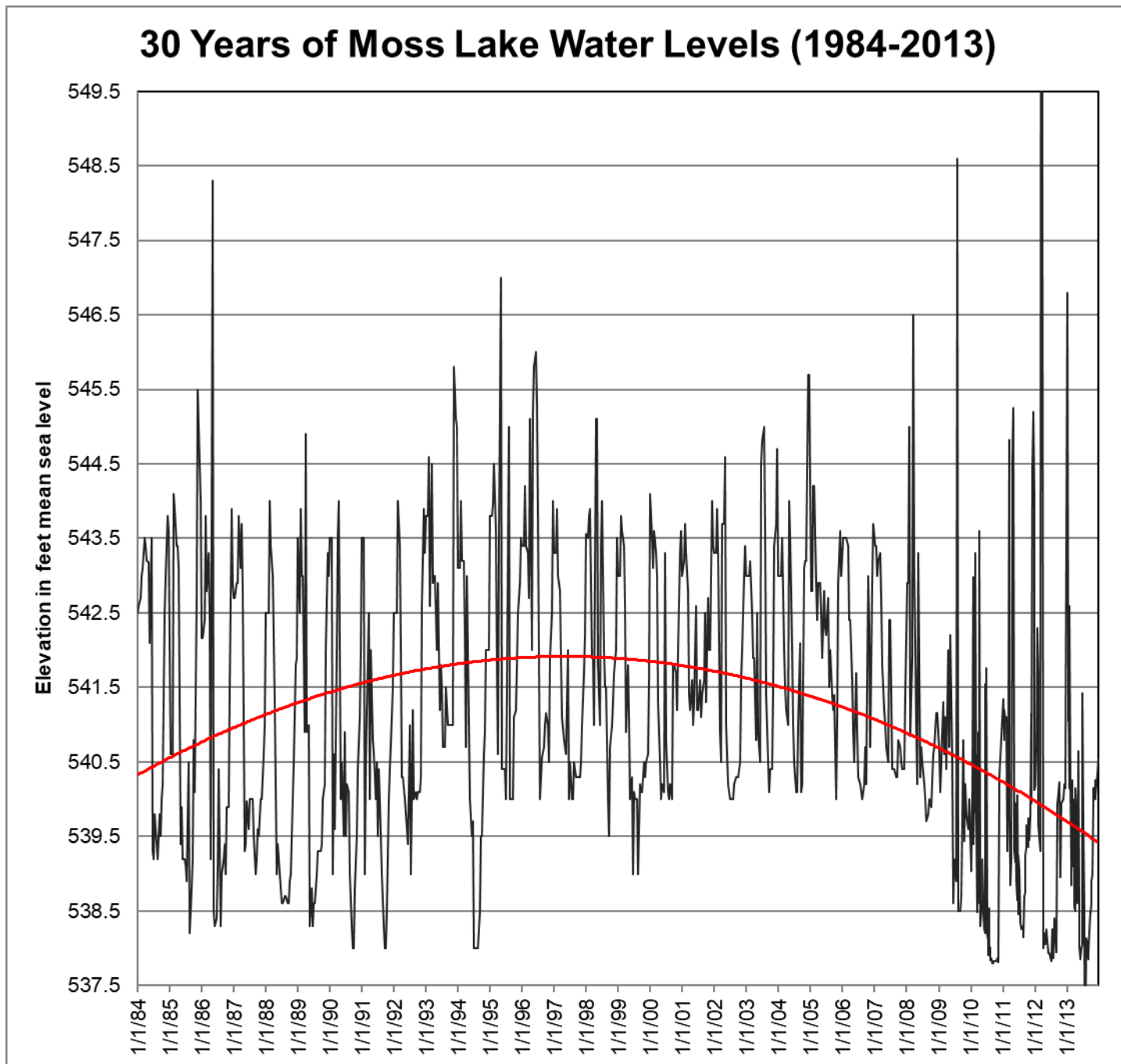


Figure 4-2. Water level record for Moss Lake 1984–2013.

4.2 National Wetlands Inventory

The National Wetland Inventory (NWI) is an extensive, ongoing survey by the USFWS, of aquatic habitats across the United States. The NWI is based on interpretation of aerial photographs, not ground surveys, and its criteria differ somewhat from those used in jurisdictional wetland delineations for permitting by the United States Army Corps of Engineers under Section 404 of the Clean Water Act. Classifications may also be somewhat outdated. Wetlands data for the MNWR refuge can be accessed using the NWI Wetlands Mapper found at this website: <https://www.fws.gov/wetlands/Data/Mapper.html>.

4.3 National Hydrography Dataset

The National Hydrography Dataset (NHD) is a vector geospatial dataset including information about the nation's lakes, ponds, rivers, streams, and other water features that are part of the USGS's National Map (data is obtained from here: <https://viewer.nationalmap.gov/basic/>). The NHD flow lines for the MNWR main unit are shown in Figure 4-3. Within the MNWR main unit approved boundaries, the flow-paths identified by the NHD can be broken down based on type, including artificial paths, ditches/ canals, perennial streams, and connectors. (Tables 4-2 and 4-3). For the inventory in Tables 4-2 and 4-3, the flow-paths labeled "stream/river unspecified" in the NHD dataset were excluded because these were generally little more than storm flow channels, located upstream of the intermittent streams. The NHD provides an approximate representation of general water flow and does not necessarily reflect actual conditions. Further, the NHD's inventory of "named features" is not necessarily all-inclusive, and some of the flowlines may be mis-categorized.

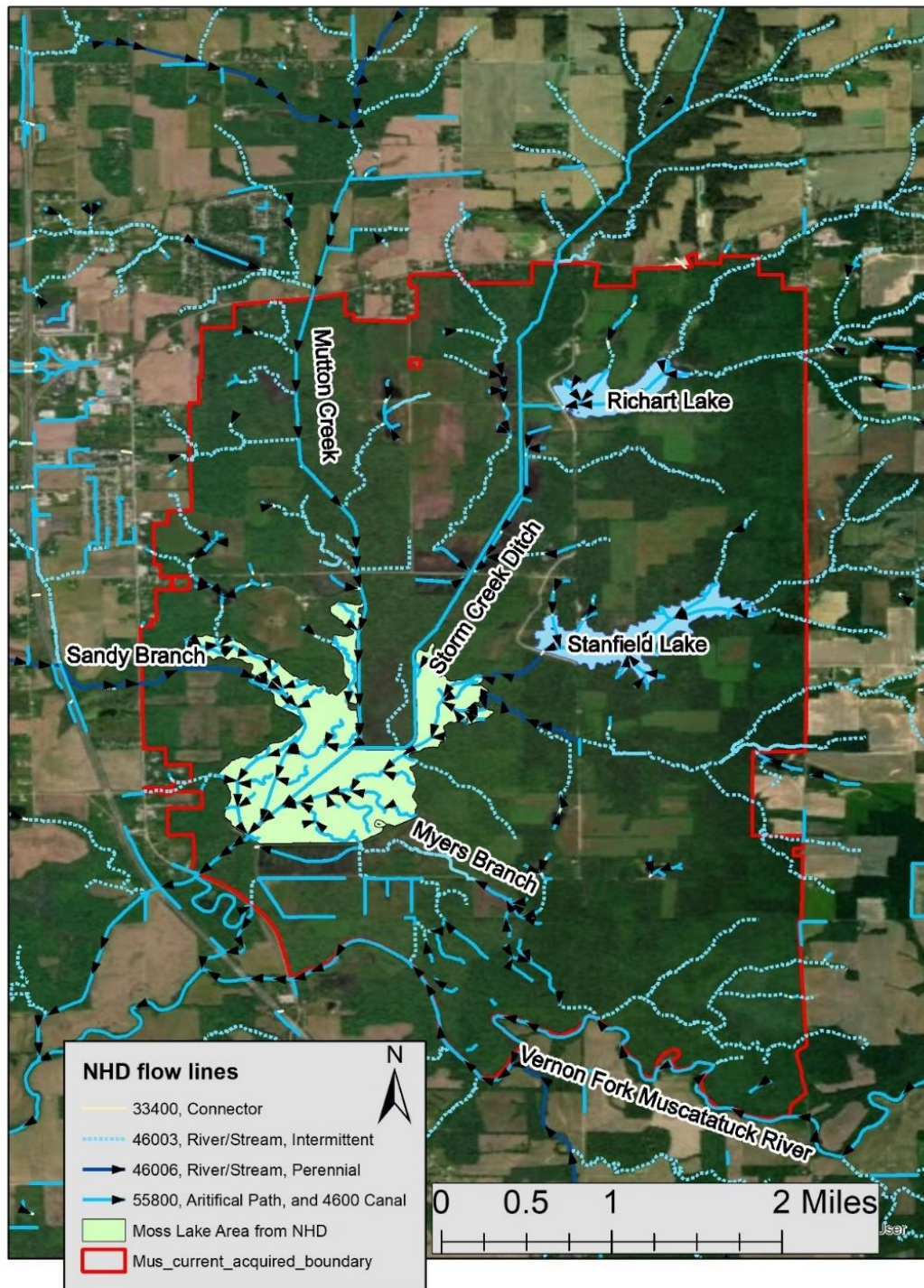


Figure 4-3. Map of NHD flow lines at MNWR main unit.

Table 4-2. Length of NHD flow lines for named streams. Unnamed and total exclude 67.2 miles categorized as “stream/river unspecified” in the NHD dataset.

Name	Total Stream Length (within a +0.25 mile buffer acq. boundary) (miles)	Percent
Vernon Fork Muscatatuck River	5.0	6.8%
Storm Creek/Storm Creek Ditch	3.7	5.1%
Mutton Creek/ Mutton Creek Ditch	4.4	6.0%
Sandy Branch	2.0	2.8%
Myers Branch	1.3	1.7%
Gum Lick Creek	0.5	0.7%
Unnamed	56.3	76.9%
Total	73.1	100.0%

Table 4-3. Length of NHD flow lines types. Excludes 67.2 miles categorized as “stream/river unspecified.”

Name	Total Stream Length (within a +0.25 mile buffer acq. boundary) (miles)	Percent
Stream/River Perennial	2.5	3.4
Stream/River Intermittent	25.9	35.5
Artificial Path	37.0	50.6
Connector	0.5	0.7
42803, Pipeline	0.5	0.7
33600, Canal/ditch	6.7	9.1
Total	73.1	100.0

Chapter 5: Water Resource Monitoring

The WRIA identified historical and ongoing water resource related monitoring on or near the MNWR. Relevant sites were evaluated for applicability based on location, period of record, extensiveness of data, sampling parameters, trends, and dates of monitoring. Water resource datasets collected near the MNWR can be categorized as water quantity or water quality monitoring of surface or groundwater.

Water quantity monitoring typically involves measurements of water level and/or volume in a surficial water body or subsurface aquifer. Water quality can include laboratory chemical analysis, deployed sensors or biotic sampling such as fish assemblages or invertebrate sampling. Biotic sampling is often used as an indicator of biological integrity, which is a measure of stream purpose attainment by state natural resource management organizations. Potential water quality threats may be identified by comparing monitoring data with recommended standards.

5.1 Water Monitoring Stations and Sampling Sites

Several resources offer water quality and quantity datasets relevant to the MNWR refuge and were utilized in the creation of MNWR refuge's water monitoring site inventory:

- Data for historical sampling locations can be retrieved through the EPA STORET (STOrage and RETrieval; <http://www.epa.gov/storet>) database. This data warehouse is a repository for water quality, biological, and physical data used by state environmental agencies, EPA and other federal agencies, universities, and private citizens.
- Water quantity and quality data for active and inactive monitoring sites can also be accessed from the USGS National Water Information System (NWIS) database (<http://www.waterqualitydata.us>).

The WRIA identified 4 monitoring stations that are considered applicable to MNWR refuge's water resources, including one surface water monitoring sites (with stream gauging by USGS and water quality monitoring by the Indiana Department of Environmental Management), and 2 active USGS groundwater monitoring stations (Table 5-1). Also, there are 3 USGS stream gauging locations that are either within 10 miles of the main unit of MNWR or upstream of the refuge with a long term monitoring dataset. Relevant water monitoring locations are listed in Table 5-1 and shown in Figure 5-1.

Table 5-1. Water monitoring stations relevant to MNWR

Site Name	ID and Link	Location	Elevation	Notes	Record maintained by:
Vernon fork Muscatatuck River at Vernon, IN	USGS-03369500	Latitude 38°58'35" Longitude 85°37'11" NAD27	584.50 feet above NAVD88	Discharge (1939-present)	USGS Indiana Water Science Center
Jennings 3 (JN 3) (well site)	USGS-385601085365701	Latitude 38°56'01", Longitude 85°36'57" NAD27	718 feet above NGVD29	Depth to water (1984-present)	USGS Indiana Water Science Center
JACKSON 1 (JK1)	USGS-385542086005601	Latitude 38°55'42.3", Longitude 86°00'56.3"	548 feet above NGVD29	Depth to water (2016-present)	USGS Indiana Water Science Center
Vernon Fork, Co. Rd. 60 s Vernon,	INSTOR WQX-2596	Latitude 38°58'35" Longitude 85°37'12" NAD27	584.50 feet above NAVD88	Water quality data (1998-present)	Indiana Department of Environmental Management
Other activate USGS stream gauging locations with long-term datasets nearby.					
Muscatatuck River at Deputy, IN	USGS-03366500	Latitude 38°48'15" Longitude 85°40'26" NAD27	540.00 feet above NAVD88	Discharge (1948-present), peak streamflow (1949-2015), some temperature and suspended sediment data (1968-2009), some water quality data (1993-2009).	USGS Indiana Water Science Center
East Fork White River at Seymour, IN	USGS-03365500	Latitude 38°58'57" Longitude 85°53'57" NAD83	550.26 feet above NAVD88	Discharge (1927-present), peak streamflow (1913-present), some suspended sediment data (1966-1981)	USGS Indiana Water Science Center
Brush Creek near Nebraska, IN	USGS-03368000	Latitude 39°04'13" Longitude 85°29'10" NAD27	716.64 feet above NGVD29	Discharge (1955-present), peak streamflow (1956-present)	USGS Indiana Water Science Center

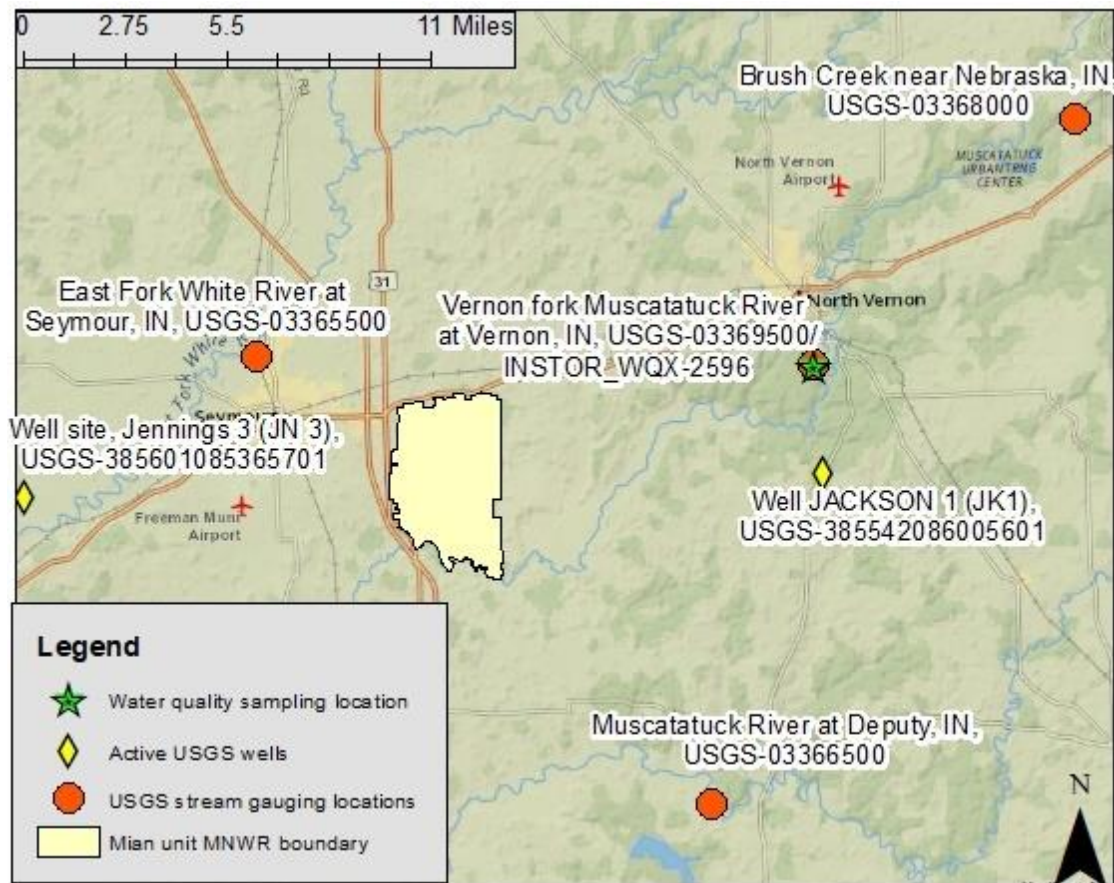


Figure 5-1. Relevant water quality monitoring locations near the main unit of the MNWR.

5.2 Surface Water Quantity

The patterns in annual discharge at the Vernon Fork Muscatatuck River at Vernon, IN shows a similar trend to the HCDN gauging locations (described in section 5.3 below). There is no significant linear trend in the peak annual discharge between 1940 to 2016, and actually a slight, though insignificant, decreasing trend, which is somewhat surprising because of the observed increase in extreme precipitation events over this time period for this region (Kunkel et al. 2003). The average annual discharge does show a significant ($p=0.03$) linear increase over this period, with the most recent 30 year (1986 to 2016) average annual discharge higher than the 1941–1985 average annual discharge by a factor of 1.15. However, this dataset is skewed by years with exceptionally low flow occurring in 1941 and 1954. When these low flow years are excluded, there is not a significant linear trend in the average annual discharge ($p=0.13$) at this location. The average monthly discharge tends to be higher in the winter and spring and lower in the summer and fall and the maximum daily discharge occurring in each month follows a similar pattern (Figure 5-3).

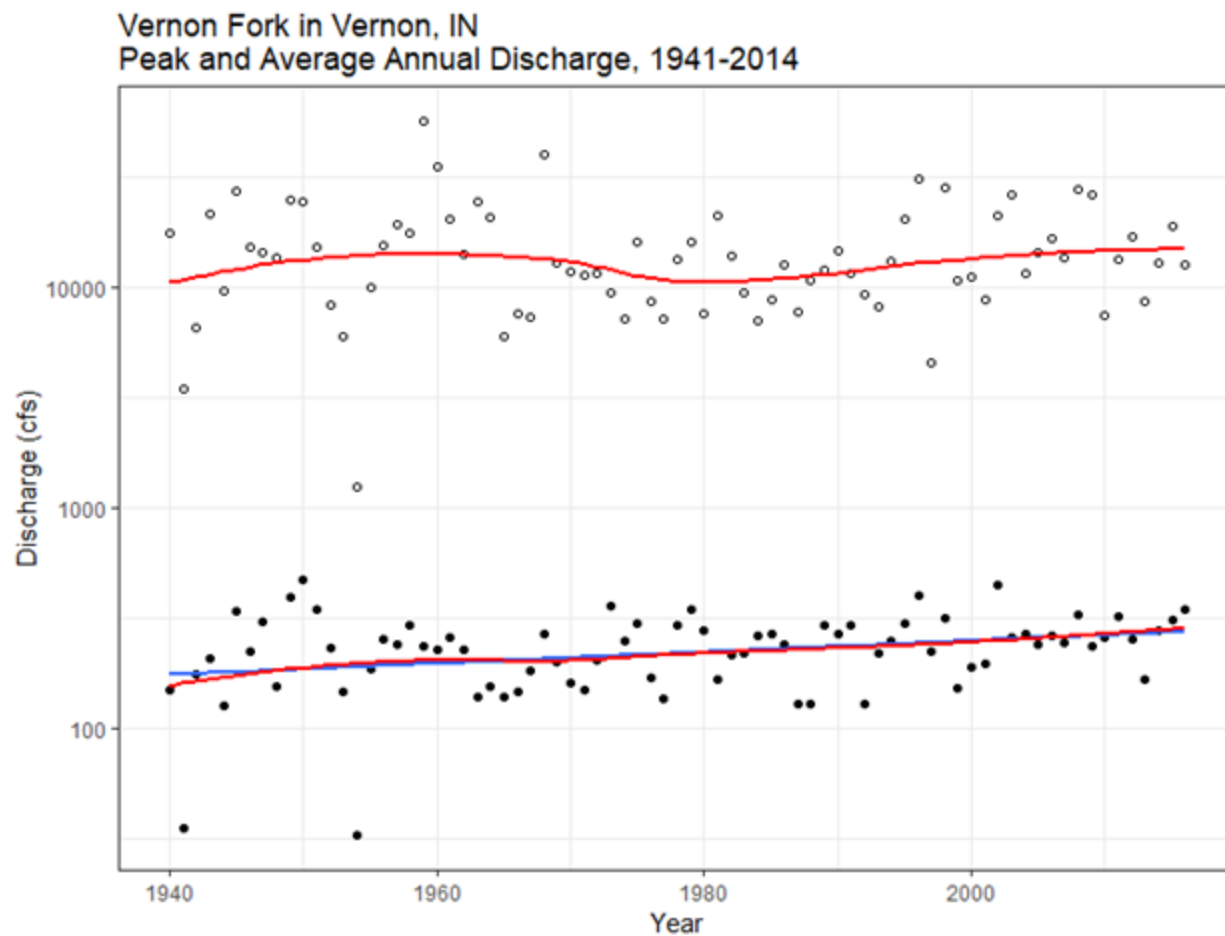


Figure 5-2. Peak annual (open circles) and average annual (closed circles) discharge at the Vernon Fork Muscatatuck River in Vernon, IN upstream of the refuge. Blue line indicate linear trend line. The red lines represents a polynomial smoothing of the annual data.

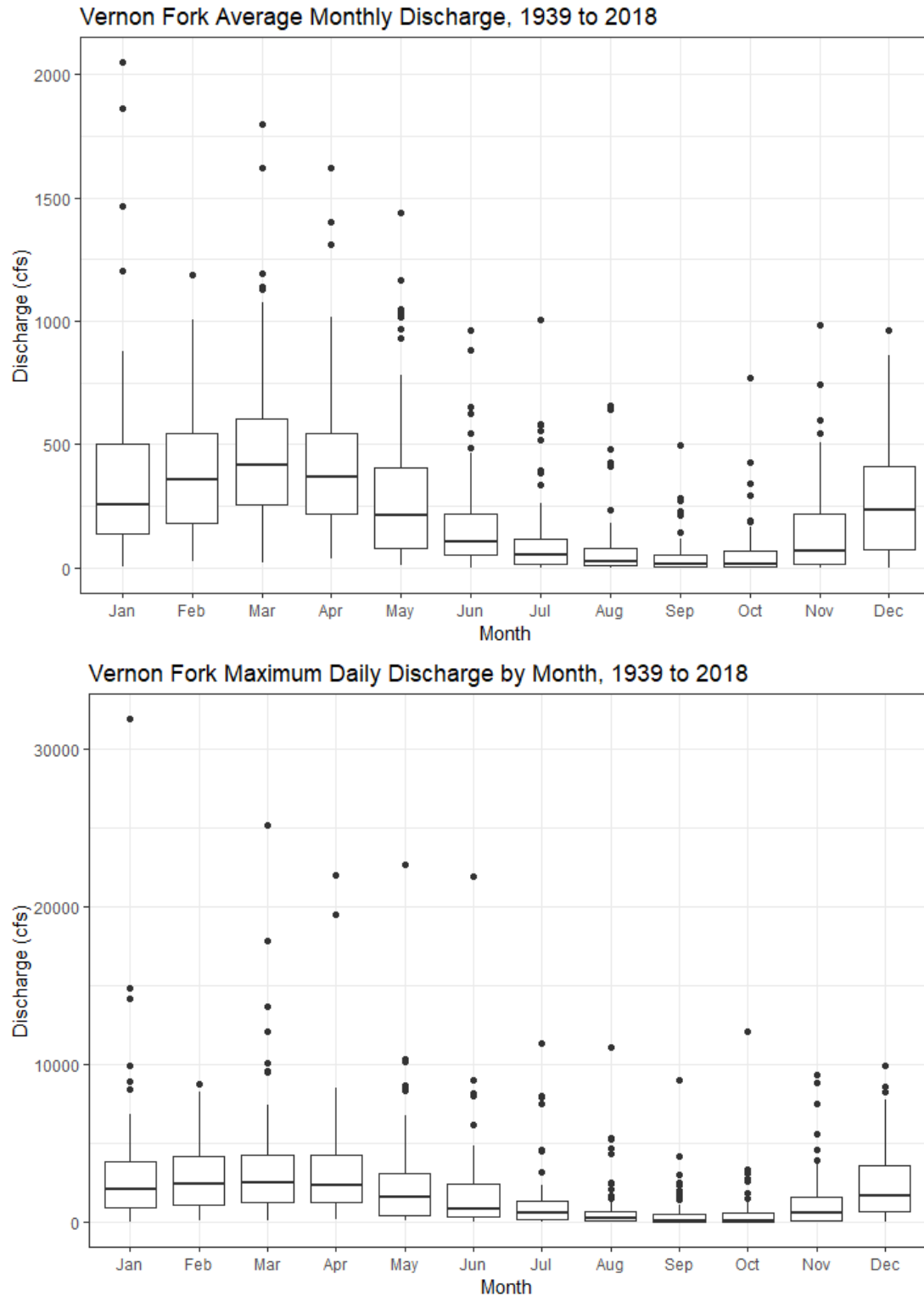


Figure 5-3. Average monthly (top) and maximum daily (bottom) discharge by month at the Vernon Fork Muscatatuck River in Vernon, IN (USGS-03369500) from 1939–2018. Note the difference in scales for the two plots.

5.3 Hydroclimatic Data Network (HCDN)

Reference hydrographs obtained from the Hydro-Climatic Data Network (HCDN) provide additional context for the assessment of trends in surface water quantity. The HCDN is a network of USGS stream gages located within relatively undisturbed watersheds, which are appropriate for evaluating trends in hydrology and climate that are affecting flow conditions (Slack et al., 1992, Lins 2009). This network attempts to provide a look at hydrologic conditions without the confounding factors of direct water manipulation and land use changes. Annual peak discharge and average annual discharge trends were compared for this analysis. The nearest HCDN sites were chosen to represent the regional hydroclimate in the area surrounding the MNWR. The nearest stations that meet the HCDN requirements are the Muscatatuck River in Deputy, IN (USGS 03366500), with a period of record from 1949 to present and a drainage area of 293 square miles, and Brush Creek near Nebraska, IN (USGS 03368000), with a discharge record from 1956 to present and a drainage area of 11.4 square miles (Table 5-1, Figure 5-1).

These gauging locations show a slight, but statistically insignificant increasing trend in peak annual discharge. However, both locations show a significant linear increase in average annual discharge (with $p=0.03$ and $p=0.002$ for the Muscatatuck River, and Brush Creek, respectively.) The most recent 30 year (1986-2016) mean average annual discharge is higher than the 1949 (or 1956) to 1985 mean by a factor of 1.15 and 1.25 for the Muscatatuck River and Brush Creek, respectively. However, for the Muscatatuck River gauging location this trend is skewed by an exceptionally low flow year in 1954. When this low flow year is removed, the linear increase in average annual discharge is only marginally significant ($p=0.07$).

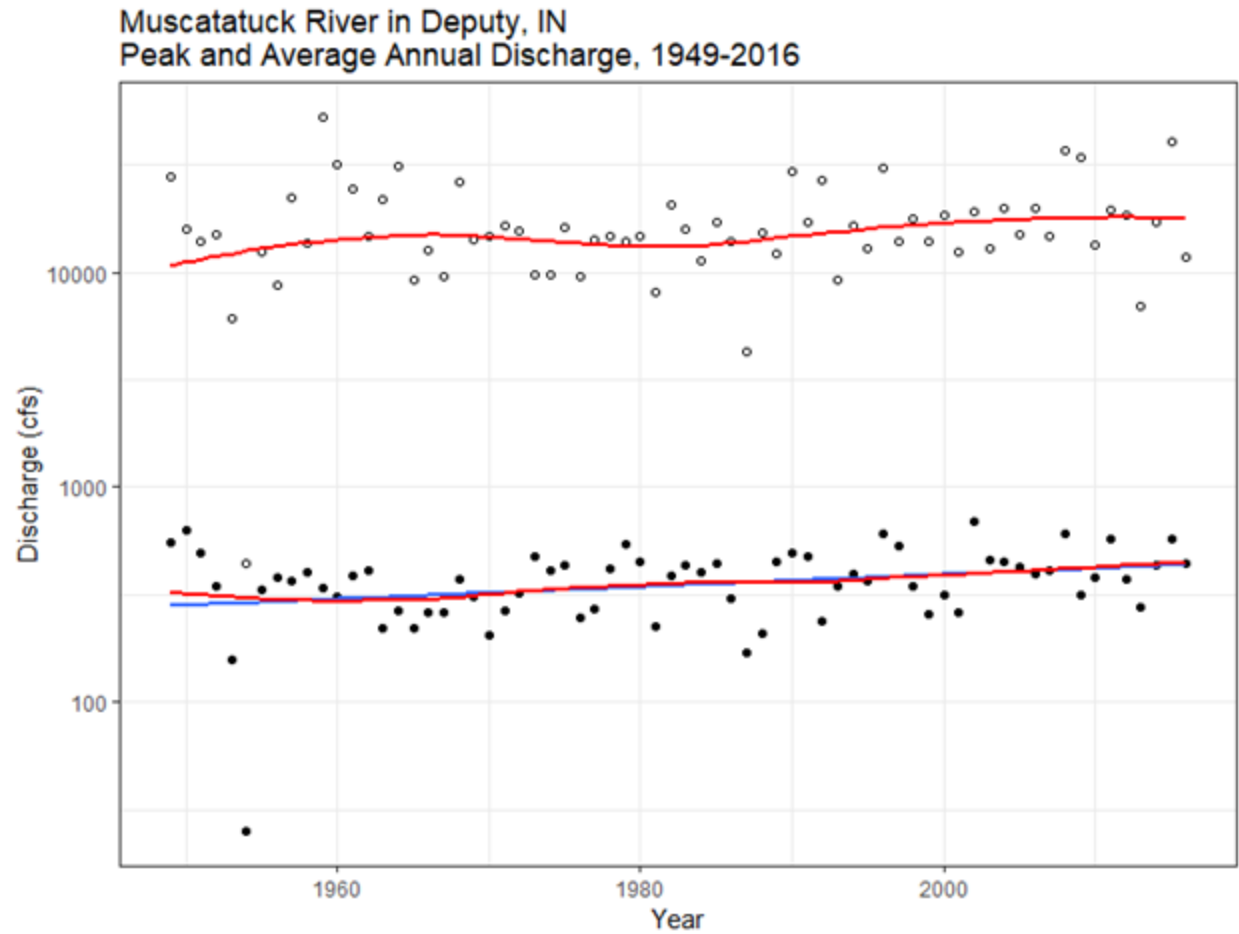


Figure 5-4. Peak annual (open circles) and average annual (closed circles) discharge at the Muscatatuck River in Duputy, IN upstream of the refuge. Blue line indicate linear trend line. The red lines represents a polynomial smoothing of the annual data.

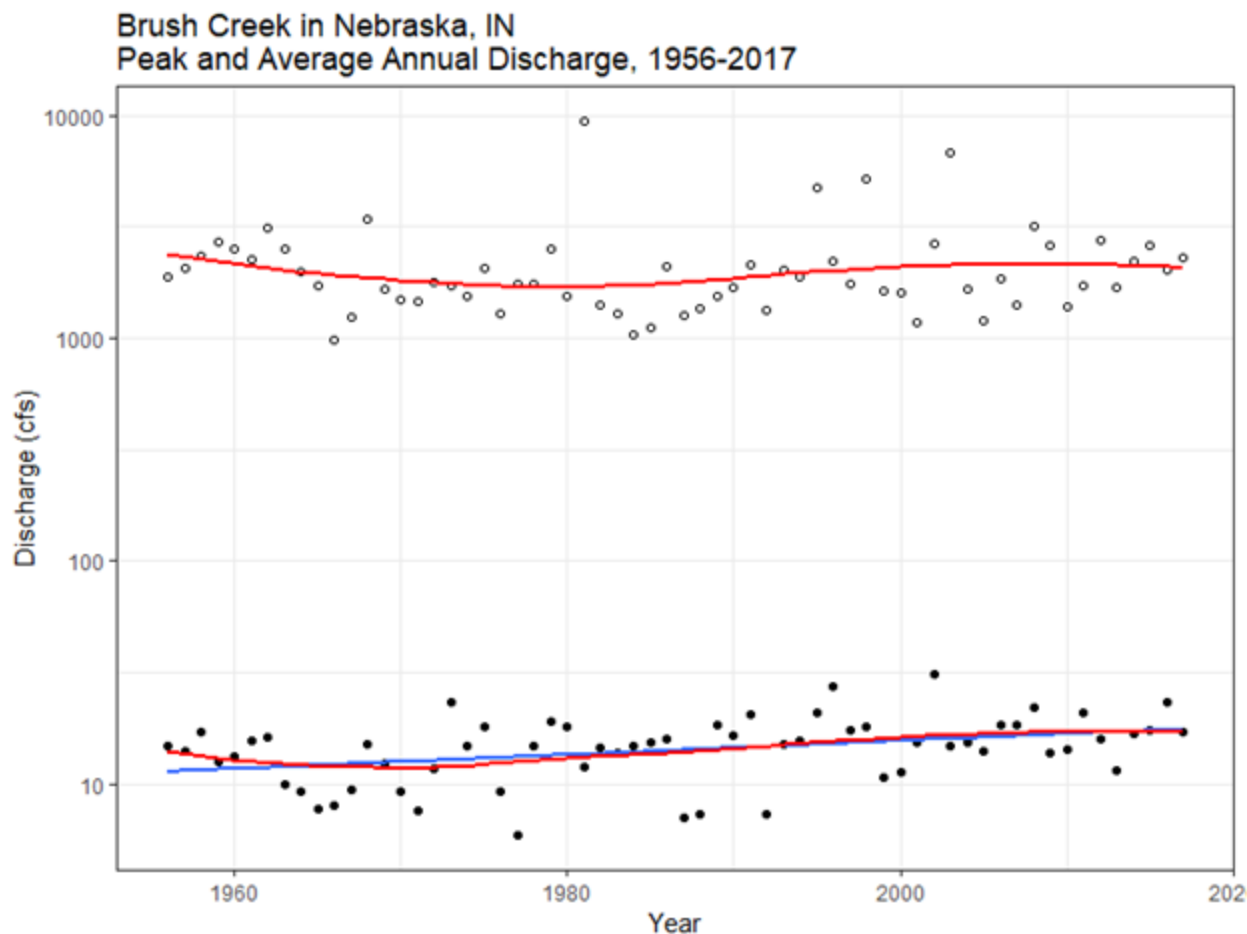


Figure 5-5. Peak annual (open circles) and average annual (closed circles) discharge at Brush Creek in Nebraska, IN upstream of the refuge. Blue line indicate linear trend line. The red lines represents a polynomial smoothing of the annual data.

5.4 Groundwater Quantity

The presence of the acidic spring seepage in the MNWR (as well as the karst features in other parts of the Muscatatuck River watershed) suggests a complex hydrogeology in the region. Two active USGS ground water monitoring wells are located within 10 mi east (JN 3) and west (JK 1) of the refuge (Figure 5-1). The location east of the refuge (JN 3) has a longer time series (1984 to present) than the JK 1 well (2016 to present). The hydrographs for these two wells are very different. The JK 1 well has larger fluctuations in water level and a higher water table than the JN 3 well (Figure 5-6). In addition, the JK 1 well has pronounced drawdowns, observed in during July and August, possibly suggesting the impact of agricultural irrigation, or other pumping in the vicinity of this particular well. However, refuge staff have observed that there is very little agricultural irrigation in the immediate vicinity of the MNWR. Due to the complex hydrogeology of this region, it is likely that neither of these wells is fully representative of the actual ground water conditions under the refuge.

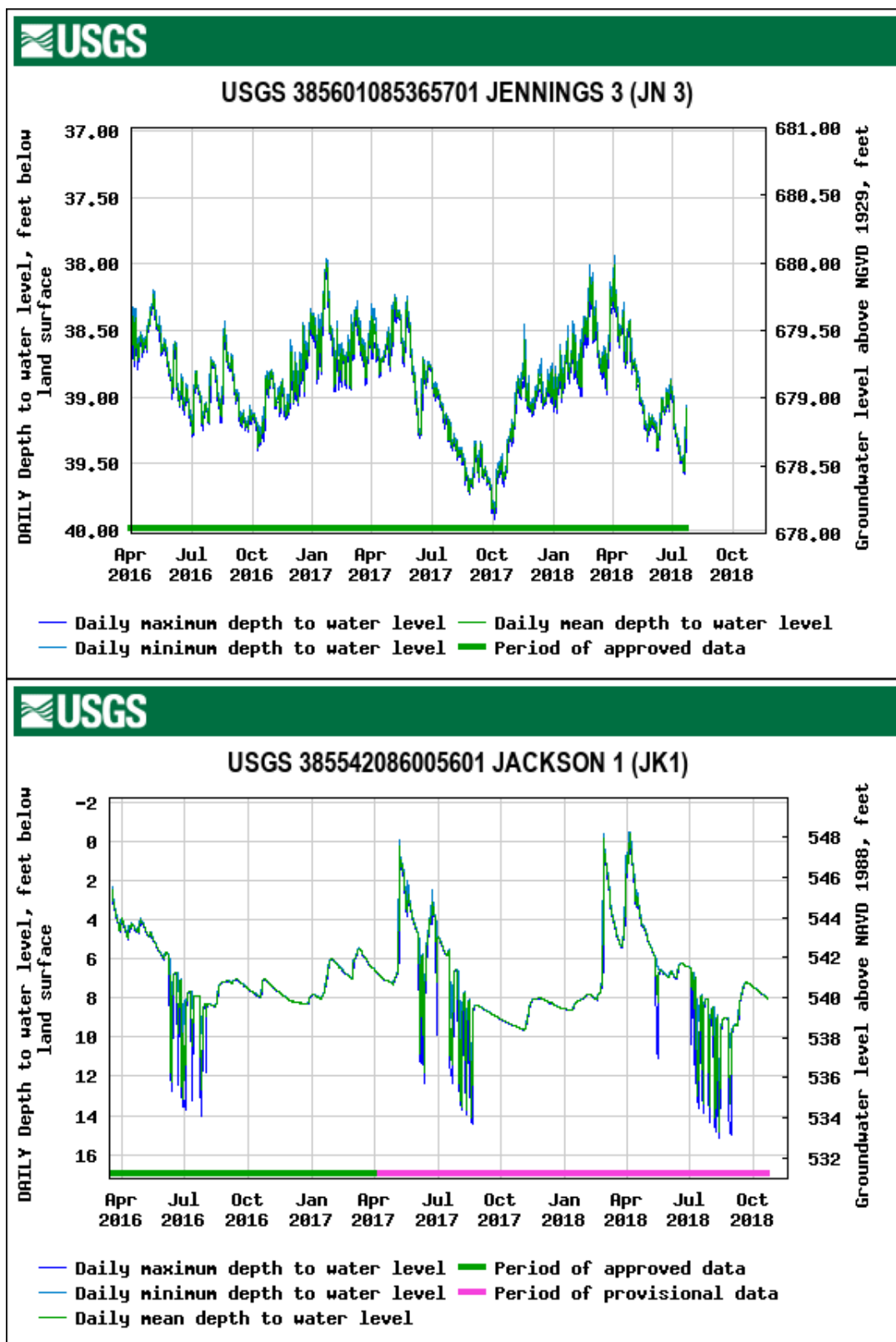


Figure 5-6. Two years of well hydrograph data from active wells near the MNWR. Figure produced by NWIS Water Mapper Tool <https://waterdata.usgs.gov/nwis>

Daily and monthly water level data is available from 1984 to present at the JN 3 USGS well site located east of the MNWR main unit. Over the period of record, the JN 3 well seems to have a generally increasing trend in both the July and the annual average water level (Figure 5-7). However, there is some uncertainty in this trend because of missing data from 2002–2015.

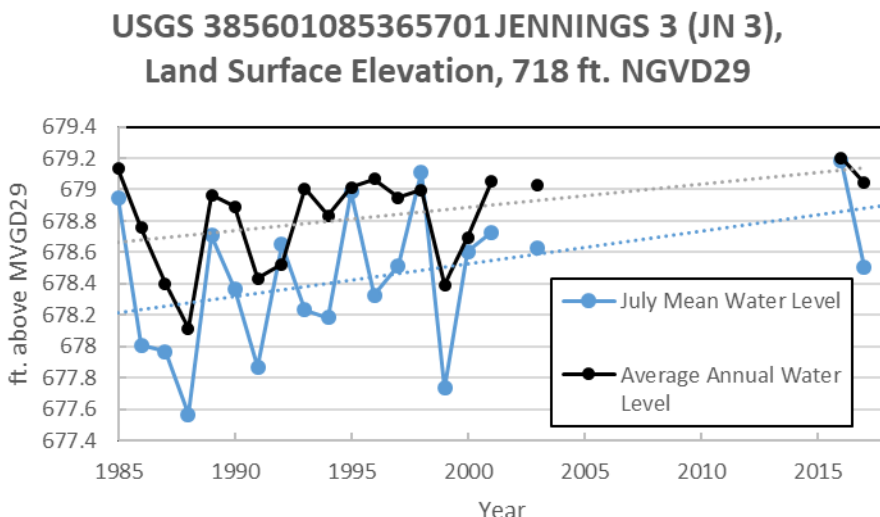


Figure 5-7. Average annual and July mean water level at the JN3 well site located ~10 miles east of the MNWR main unit from 1984–2017.

There is a lack of hydrological/hydrogeological monitoring data at the acidic spring seepage area in the MNWR. Thus, it is difficult to determine the vulnerability of this spring and the dependent rare ecological area. Still, the observed trend in increasing water level at the JN 3 well and the limited agricultural irrigation in near the MNWR mean that this spring is not likely under threat from hydrogeological changes. A larger apparent threat to this area is inundation from beaver dams and siltation along the Mutton Creek. Also, several seepage springs exist along the western edge of Moss Lake, suggesting a general ground water influence in this area. In the case of Moss Lake, the groundwater inputs have not been quantified but likely are much smaller than the surface water inputs from Mutton Creek, Storm Creek, and the Sandy Branch.

5.5 Water Quality Criteria

The Environmental Protection Agency (EPA) developed technical guidance manuals and nutrient criteria for the protection of aquatic life in various types of waters specific to different ecoregions. Those developed for rivers/streams and lakes/reservoirs for ecoregion VI are summarized below (US EPA 2000; Table 5-2). These criteria are relevant to individual streams and lakes within MNWR's RHI.

Additional information related to the application of federal water quality standards and regulations to wetlands is provided by the EPA's Water Quality Standards Handbook (<http://water.epa.gov/lawsregs/guidance/wetlands/quality.cfm>). Procedures outlined in this handbook are used when specific criteria for wetlands are developed.

Table 5-2. Nutrient criteria for rivers/streams and lakes/reservoirs established for Ecoregion VI (Corn Belt and Northern Great Plains, EPA 2000)

Parameter	Ecoregion VI	
	Rivers and Streams	Lakes and Reservoirs
TP (ug/L)	76.25	37.5
TN (mg/L)	2.18	0.781
Chl <i>a</i> (ug/L)	2.7 (Fluorometric)	8.59 (Fluorometric)
Turb (FTU)	6.36	-
Secchi (m)	-	1.356

In addition to the basic water quality parameters listed above, the EPA has compiled national recommended water quality criteria for roughly 150 pollutants (<http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm>) to provide guidance in developing state-specific standards. The development of state and federal water quality standards requires consideration of the existing and potential uses of water bodies. Different uses often require different levels of protection for specific pollutants. Water bodies may have several different uses associated with them, such as aquatic life and recreation, in which case criteria for each pollutant are determined based on the most vulnerable designated use (<http://water.epa.gov/drink/contaminants/#List>). Impairment listings for assessed waterbodies relevant to MNWR refuge are discussed below.

5.6 Surface Water Quality

303(d) Assessments

Section 303(d) of the Clean Water Act requires that each state identify water bodies where water quality standards are not met based on designated usage. The State of Indiana Department of Environmental Management (IDEM) produced a list of 303(d) impaired bodies in 2016, and this list was updated in August 2018, with only minor changes near the MNWR. Shape files were available from IDEM for the 2016 list, which were utilized to identify any impaired streams, rivers, or lakes in close proximity to the MNWR refuge. The following table (Table 5-3) lists the water bodies with known designated use(s) impaired along with the cause(s) of those impairment(s) for streams directly flowing into the MNWR or within the refuge boundary. Water impairments near the refuge are typically caused by E. Coli, low dissolved oxygen, and impaired biotic communities. Upstream of the MNWR, along the Vernon Fork Muscatatuck River and tributaries, a number of locations are also listed as impaired for a similar set of causes including, low dissolved oxygen, E. Coli, impaired biotic communities, and nutrients; also, a few locations along the Vernon Fork have been listed as impaired for mercury levels in fish tissue. However, for the reach adjacent to or immediately upstream of the MNWR, the Vernon Fork of the Muscatatuck River is not listed as impaired. For the Restle Unit, there are no 303(d) listed waters located within 0.25 mi of the refuge boundary, but within the same HUC 12 watershed, Beanblossom Creek is listed as impaired for E. Coli, PCBs in fish tissue, dissolved oxygen, and impaired biotic communities. A map of impaired streams and lakes on the 2016 Indiana 303(d) impaired stream list is shown in Figure 5-8.

Table 5-3. 303(d) listed impaired water bodies on or within 0.25 mi of the MNWR, from the 2016 303(d) list.

ASSESSMENT UNIT NAME	CAUSE OF IMPAIRMENT	Length of impaired streams within 0.25 mi of the refuge boundary
MUTTON CREEK AND UNNAMED TRIBUTATIES	E. COLI, DISSOLVED OXYGEN, IMPAIRED BIOTIC COMMUNITIES	8.26
SANDY BRANCH	IMPAIRED BIOTIC COMMUNITIES	3.2
STORM CREEK	IMPAIRED BIOTIC COMMUNITIES, DISSOLVED OXYGEN,	7.06
STORM CREEK - UNNAMED TRIBUTARIES	DISSOLVED OXYGEN, IMPAIRED BIOTIC COMMUNITIES	1.98

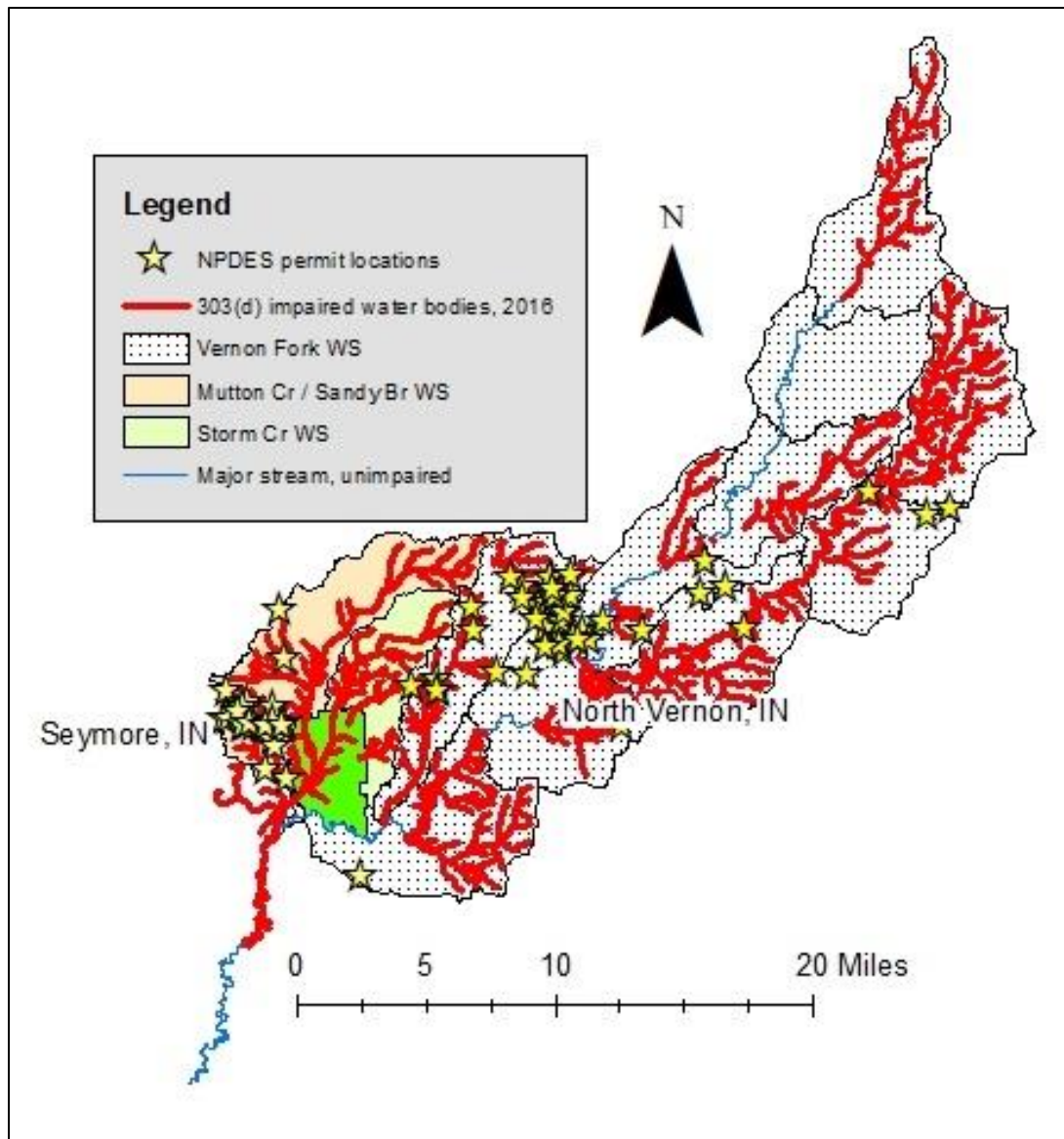


Figure 5-8. NPDES and 2016 303(d) stream near the Muscatatuck National Wildlife Refuge.

NPDES Permits

Under the Clean Water Act, the discharging of point-source pollutants into “waters of the United States” requires a National Pollutant Discharge Elimination System (NPDES) permit. In Indiana, NPDES permits are issued by the Indiana Department of Environmental Management (IDEM) and overseen by the U.S. EPA. Within the Mutton Creek and Storm Creek watersheds there are 25 active NPDES permits (see Table B-1 in Appenix B). In the larger watershed of the Vernon Fork Muscatatuck River, there are 51 active NPDES permits issued upstream of the MNWR (see Table B-2 in Appendix B). The only “major” discharge permits in the MNWR RHI is the North Vernon, IN wastewater treatment plant (WWTP), which discharges into the Vernon Fork Muscatatuck River and is rated at 2.2 MGD (3.4 CFS) (IDEM, 2010). Within the RHI for MNWR, the NPDES permit sites are clustered around the larger populations centers of Seymour and North Vernon (Fig 5-8).

MNWR River/Lake Water Quality

In this agricultural landscape (~60.5% of the watershed land use is agriculture or pasture land) (Simon, 2008), the most pertinent water quality issues facing the refuge are nutrients and sediment loads. This is reflected in the fact that many of the 303(d) streams in the vicinity of the refuge are impaired for low dissolved oxygen and biotic communities. The impairment for *E. Coli* on Mutton Creek may be caused by poorly functioning sewage outfalls in this watershed, as suggested by Simon (2008). In particular, this may be caused by sewage overflows from residential sub-divisions upstream of the refuge during high flow periods (communication with refuge staff).

Aquatic Chemistry on MNWR

In 2007, a comprehensive water quality, habitat, and biotic survey was conducted by the Bloomington Indiana Ecological Services Field Office for the refuge and watershed upstream of the refuge. The findings of this study are compiled in a report (Simon, 2008). Based on this study, the average total N concentration near the MNWR was found to be 0.51 ± 0.60 mg/l, which is below the EPA water quality criteria for the protection of aquatic life of 0.781 mg/l for lakes and reservoirs. However, individual sampling locations throughout the refuge do exceed the EPA recommended levels for lakes or streams. The average total phosphorus concentration was 110 ± 170 µg/l but there is substantial variation for the sampling locations throughout the refuge, with phosphorus concentrations of samples ranging 30–960 µg/l. This average level of total phosphorus exceeds the EPA recommendations for both lakes (37.5 µg/l) and streams (76.25 µg/l) for the protection of aquatic life. Many of the sampling locations on/near the MNWR area with the highest total phosphorus are located along Mutton Creek. The total suspended solids (TSS) was found to be highly variable. Excluding one high outlier of 5860 mg/l, the average measured TSS throughout the watershed is 67.2 mg/L (although a much lower median value of 9 mg/l because this data is skewed by a few high TSS values). In general throughout the MNWR, “high levels of these contaminants [arsenic, iron, phosphorus, and total solids] show agricultural affects from field tile discharge” (Simon, 2008).

Also, a single sample of relatively high mercury was observed in a pond to the east of Moss Lake on the refuge (Simon, 2008).

Aquatic Life on MNWR

Simon (2008) also observed low dissolved oxygen levels particularly in Moss Lake and to a lesser extent Stanfield Lake in the summer of 2007. Levels as low as 1.06 mg/L were observed in Moss Lake, with “levels below 4.0 mg/L considered insufficient for supporting aquatic life.” This study suggests that low dissolved oxygen is the result of stagnant shallow water (such as occurs in Moss Lake) in an agricultural watershed although the drought conditions in the summer of 2007 exacerbated the low levels of dissolved oxygen observed. “Fish species occurring in this [Moss] lake include those capable of breathing atmospheric oxygen, such as bowfin and central mudminnow.”

Based on the fish species diversity, Simon (2008) rated a biotic integrity score for water bodies on/near the MNWR. Larger streams including Mutton Creek, Storm Creek, and Vernon Fork Muscatatuck River were considered high quality (“Very Good” to “Exceptional”) based on the fish species diversity. Smaller streams and lakes on the MNWR were found to range from “fair” to “good” quality, with one location, the outlet of Richart Lake, considered “poor” quality.

Along the Sandy Branch and an unnamed tributary of Richard Lake, biotic assemblages were predicted by sodium and chloride concentrations, and Simon (2008) study notes that these contaminants “are a response signature of wastewater treatment effluents.” This may indicate failed septic systems or issues from wastewater effluent in these sub-watersheds. Much more detail on the biological integrity and the aquatic chemistry of the MNWR can be found in Simon (2008).

Temporal Trends in water quality on the Vernon Fork Muscatatuck River

The water quality sampling location on the Vernon Fork Muscatatuck River (INSTOR_WQX-2596) can be used to understand temporal patterns in water quality. At this location, water quality samples have been collected regularly over a 20 year period (1998–present). This water quality sampling location corresponds to the USGS stream gauging location on the Vernon Fork Muscatatuck River (USGS-03369500) described above, which means that water quality data can be compared to discharge. Although the majority of the MNWR water supply does not come from the Vernon Fork Muscatatuck River, this data may be reflective of the Storm Creek and Mutton Creek water quality, which have similar land use patterns throughout the watershed.

At the INSTOR_WQX-2596 sampling location, there are very slight but statistically significant linear trends in the inorganic nitrogen and total phosphorus over this 20 year period of record (Figure 5-9, and Figure 5-10), with the inorganic nitrogen concentration showing a slight increase and the total phosphorus a slight decrease over this period.

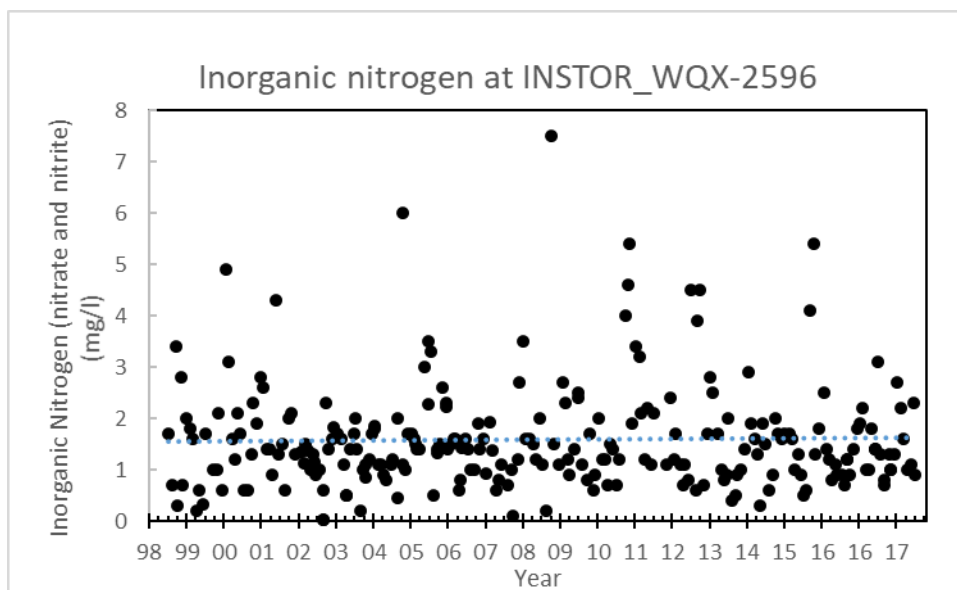


Figure 5-9. Inorganic nitrate concentration measured at INSTOR_WQX-2596 from 1998 to 2017. Dotted blue line represents a linear trend line.

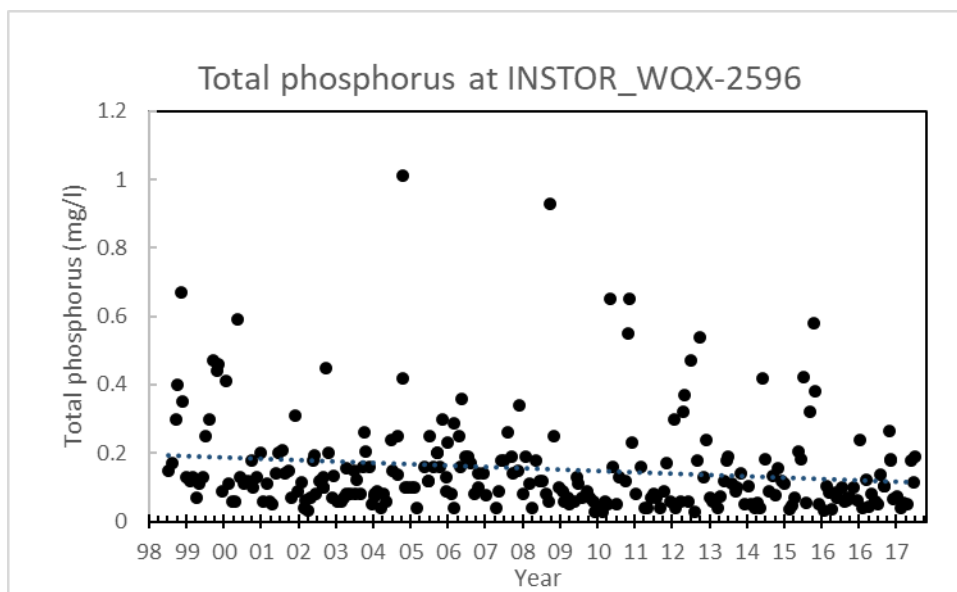


Figure 5-10. Total phosphorus concentration measured at INSTOR_WQX-2596 from 1998 to 2017. Dotted blue line represents a linear trend line.

As with the 2008 Ecological Services report (Simon, 2008) for the MNWR, the total phosphorus concentration at INSTOR_WQX-2596 is generally above the EPA criteria for ecoregion VI (table 5-2) and the total N is generally, but not always, below the EPA criteria. Interestingly, the sampling instances with the highest (and lowest) nitrate both occur during low flow periods (Figure 5-11). The sampling events with high total phosphorus either corresponds to low discharge (and high N concentrations) possibly as soluble phosphates as a result of fertilizer applications in the watershed, or during high discharge and high TSS probably associated with

mobilized sediment particles (Figure 5-12). Sampling events with TSS above 100 mg/l typically correspond to high total phosphorus (>0.25 mg/l) (Figure 5-13).

The occurrence of high levels of nitrates and total phosphorus together during discrete low-flow events suggest that this may be caused by the timing of fertilizer/slurry applications in the watershed, which would be exacerbated by low volume of flow. Also, the sampling events with the highest nitrate and total phosphorus concentrations occur during the month of October (Figure 5-14), which would correspond to fall, post-harvest fertilizer applications. This observation is particularly true for total phosphorus, which could be explained by the fact that as soluble phosphates would be most mobile shortly after fertilizer application before binding to soil minerals. The seasonal trend in inorganic nitrate concentration at this site is similar to that observed by Schwarz et al., (2018) from agriculture tile drainage, with average inorganic nitrate concentrations higher in June, July and October than in April or August. Also, it is important to note that the temporal variations in the nutrient concentrations at INSTOR_WQX-2596 would be influenced by the North Vernon waste water treatment plant (WWTP), which is permitted to discharge 2.2 million gallons per day of WWTP effluent into the Vernon Fork Muscatatuck River and is located only a few miles upstream of this sampling location. This level of discharge is comparable to the summer discharge for the Vernon Fork Muscatatuck River during a dry year. Thus, WWTP discharge also has an effect on observed water quality trends particularly at low flows. The Vernon Fork only floods over its banks into other areas of the refuge during high flows, which would generally correspond to periods of moderate inorganic nitrogen and high total phosphorus and TSS concentrations.

There are a few distinct differences between the Vernon Fork watershed and the Mutton and Storm Creek watershed, such as a generally higher percentage of urbanization (~9% in Mutton/Storm Creek WS compared to ~3.5% in Vernon Fork Watershed) (Simon, 2008). Also, the sewage outfalls from residential developments upstream on Mutton Creek are thought to occur only during high flow periods. Whereas, the North Vernon WWTP would presumably operate continuously. Still, if the trends observed on the Vernon Fork apply to the Mutton Creek and Storm Creek watersheds, than it suggests the importance of water quality sampling during low flow conditions, when the extremes of both low and high nutrient concentrations can occur.

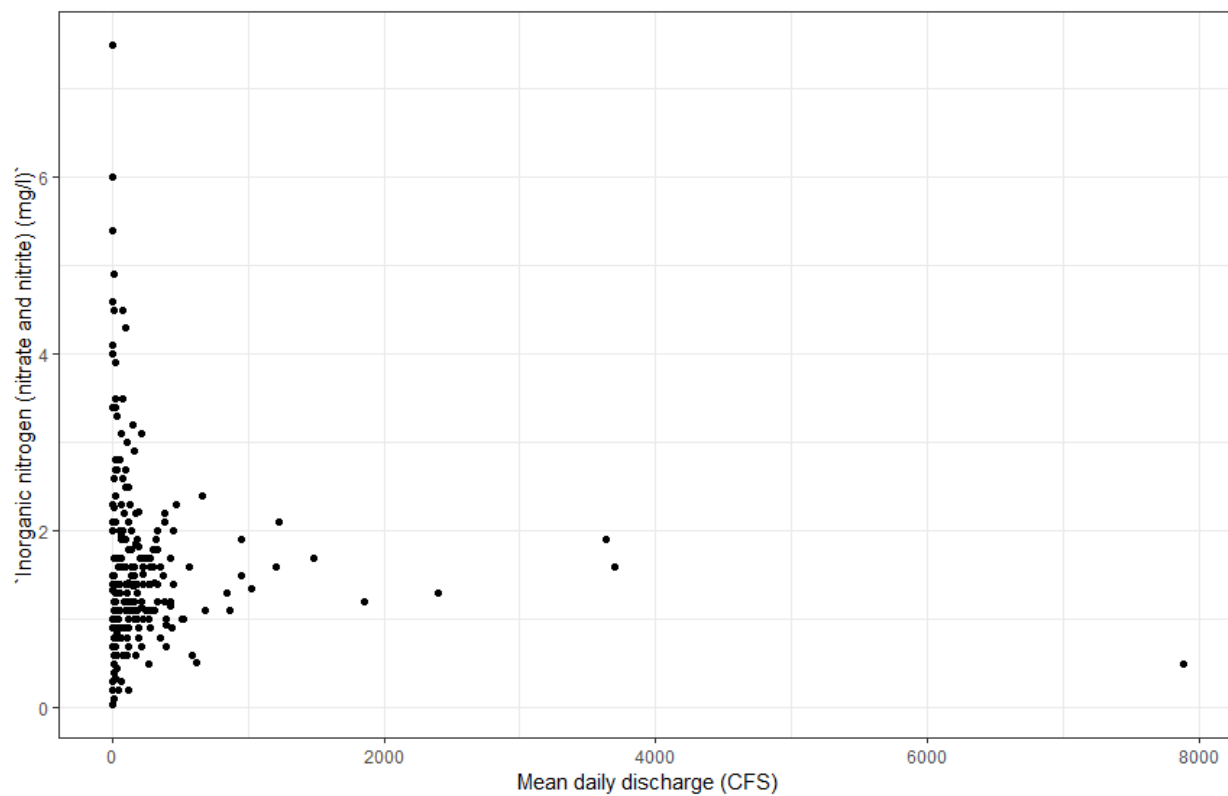


Figure 5-11. Inorganic nitrate concentration measured at INSTOR_EQX-2596 vs. mean daily discharge.

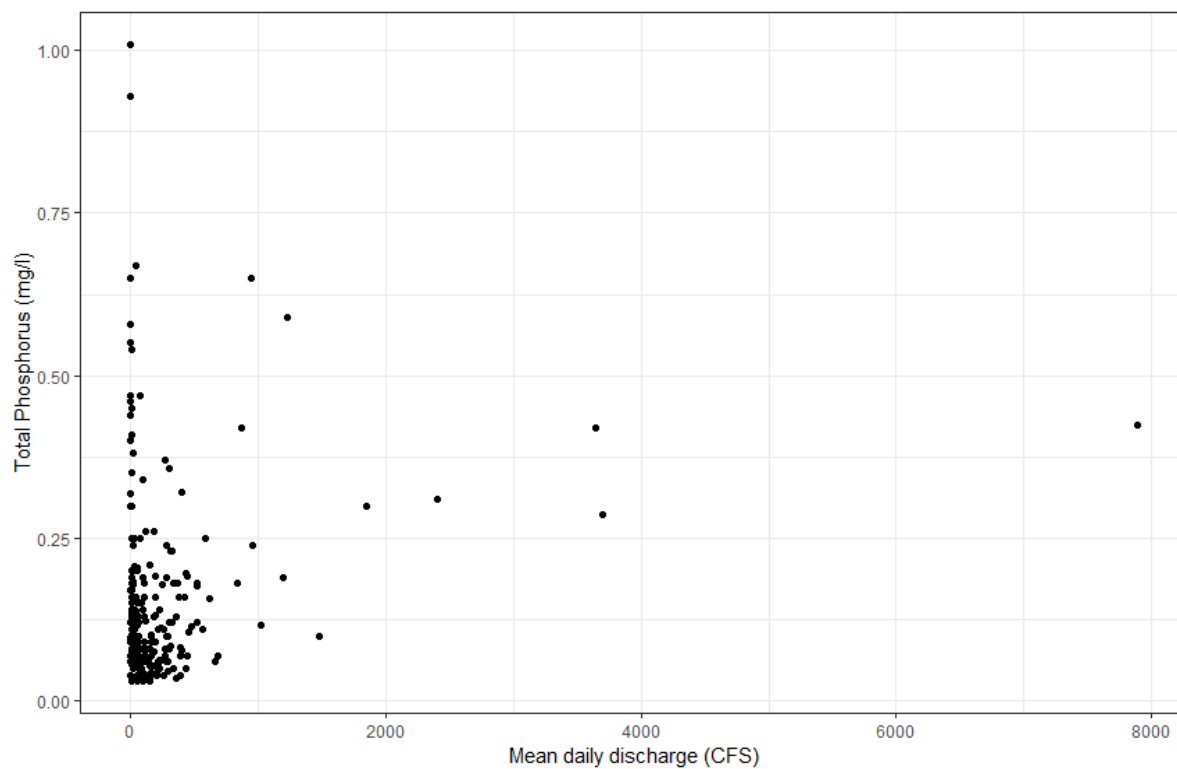


Figure 5-12. Total phosphorus concentration measured at INSTOR_EQX-2596 vs. mean daily discharge.

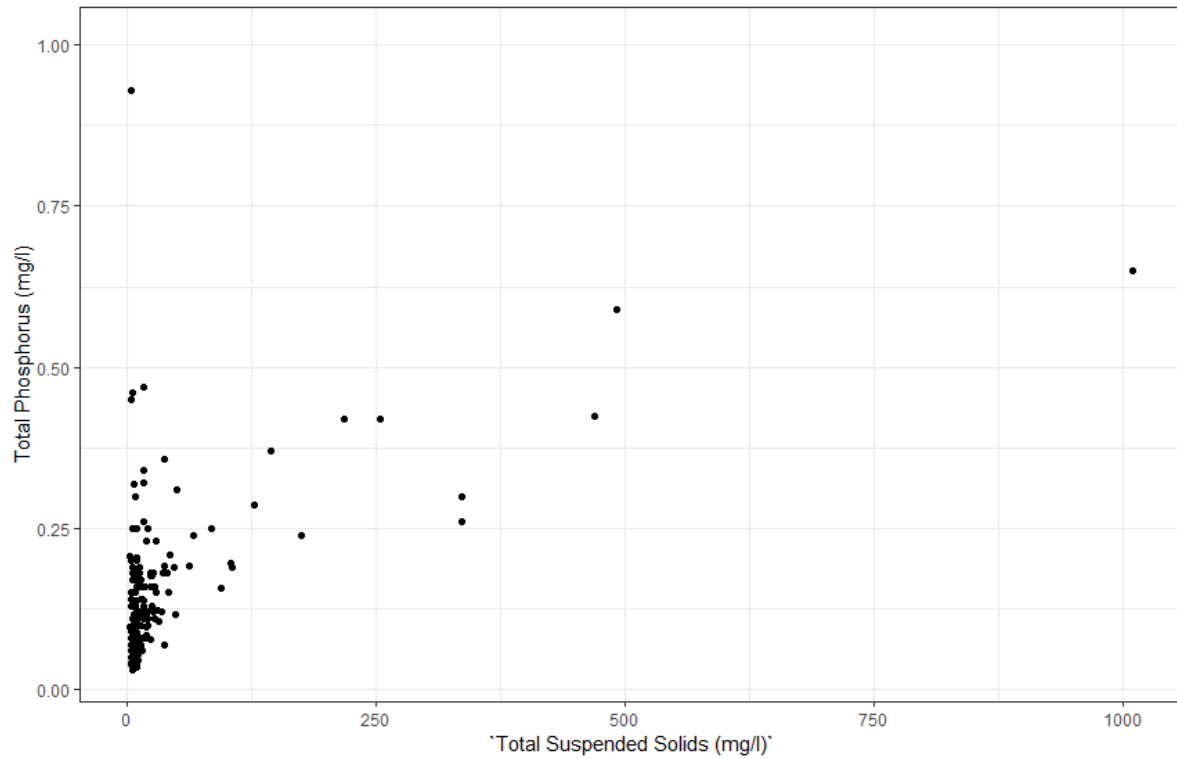


Figure 5-13. Total phosphorus concentration measured at INSTOR_EQX-2596 vs. total suspended solids (TSS) concentration.

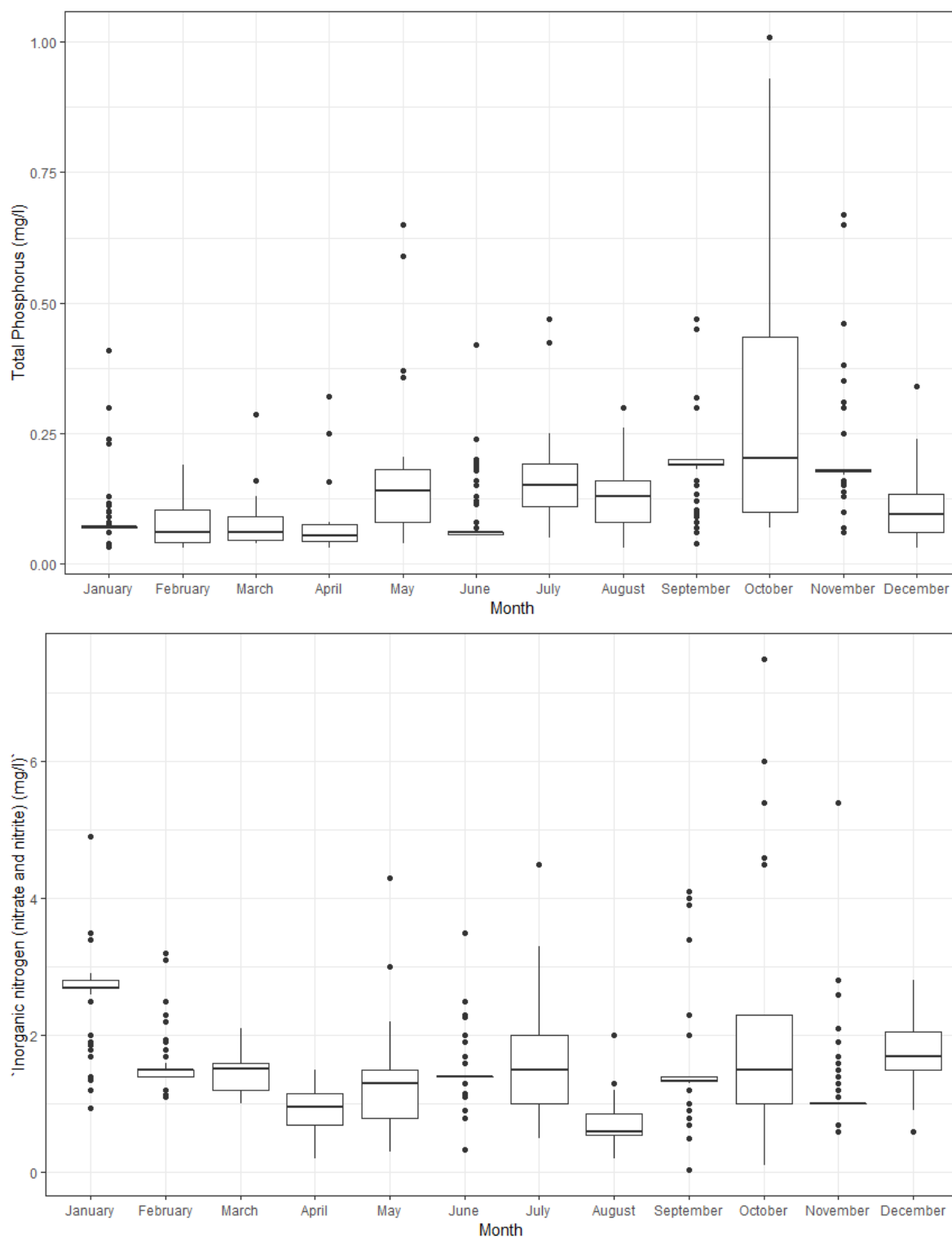


Figure 5-14. Box plot of (top) total phosphorus concentration and (bottom) inorganic N concentration by month from INSTOR_EQX-2596.

The total suspended solids (TSS) concentrations at the INSTOR_WQX-2596 is highly variable, ranging from 3 mg/l to over 1000 mg/l. The majority of the TSS measurements are quite low, with a median concentration of 8 mg/l, similar to Simon (2008). TSS becomes more variable as discharge increases (Fig 5-15) although with discrete sampling times it is difficult to determine the exact relationship between discharge and TSS. Somewhat surprisingly, many of the highest average TSS and maximum TSS measurements occur during the months of May, June, and July when crops would generally be present (Figure 5-16). The refuge staff at MNWR have expressed concerns that high sediment loads entering the MNWR cause degradation to the ditches of Storm and Mutton Creek and surrounding infrastructure. These issues are exacerbated by sediment entrapment in impoundments and behind beaver dams. It is a challenge to quantify the sediment loads, impacting the lakes and streams of the MNWR because TSS can be highly variable with respect to time. Sediment loads are difficult to characterize because sediment concentration can be highly variable with discharge. This could possibly be done with in-situ turbidity loggers upstream and downstream of the refuge or a land use based model (e.g. SWAT model). In Richart and Stanfield Lakes, the amount of sedimentation could be characterized by repeating bathymetry 10-20 years after the initial surveys were done in 2009. Further, for mitigation measures, it is necessary to characterize sediment source within the watershed, which can be done by several different means: fingerprinting the sediment characteristics in the refuge, modeling sediment loads within the watershed by means of a SWAT or similar model, or with spatial sampling throughout the watershed.

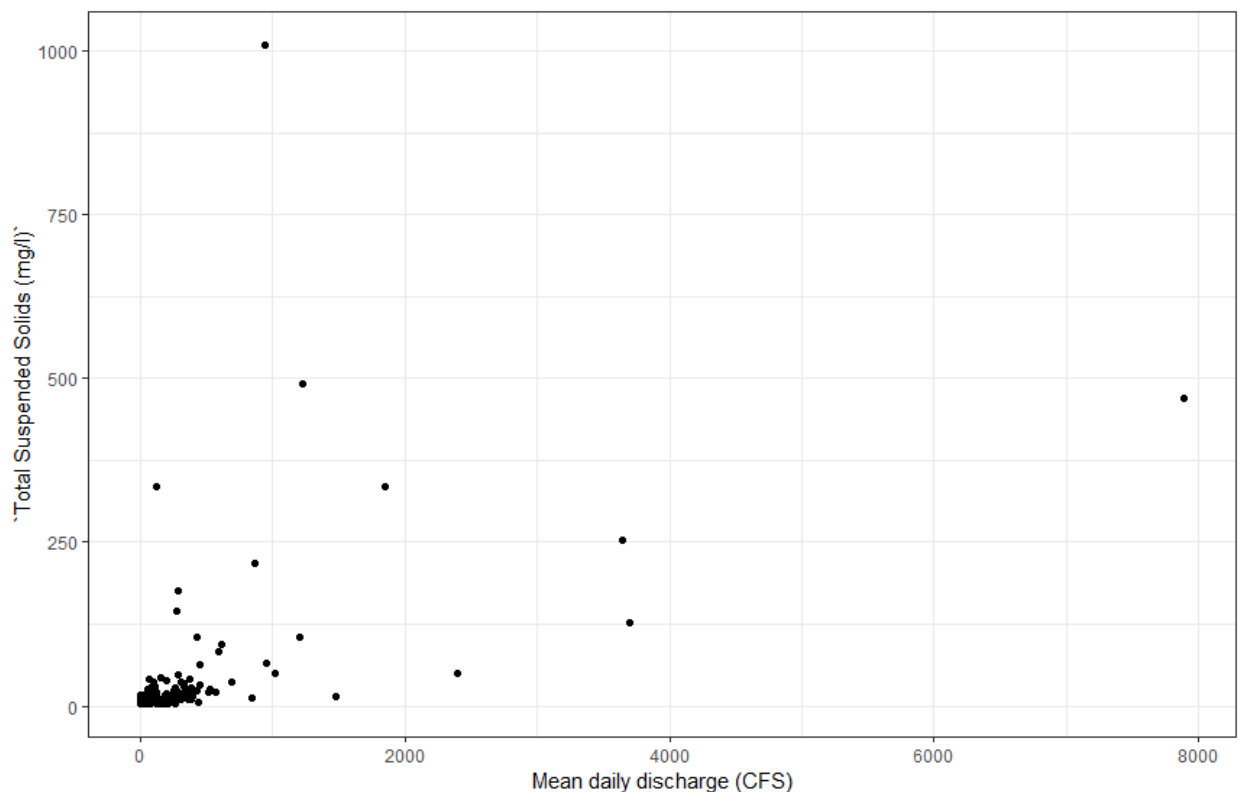


Figure 5-15. TSS concentration measured at INSTOR_EQX-2596 vs. mean daily discharge.

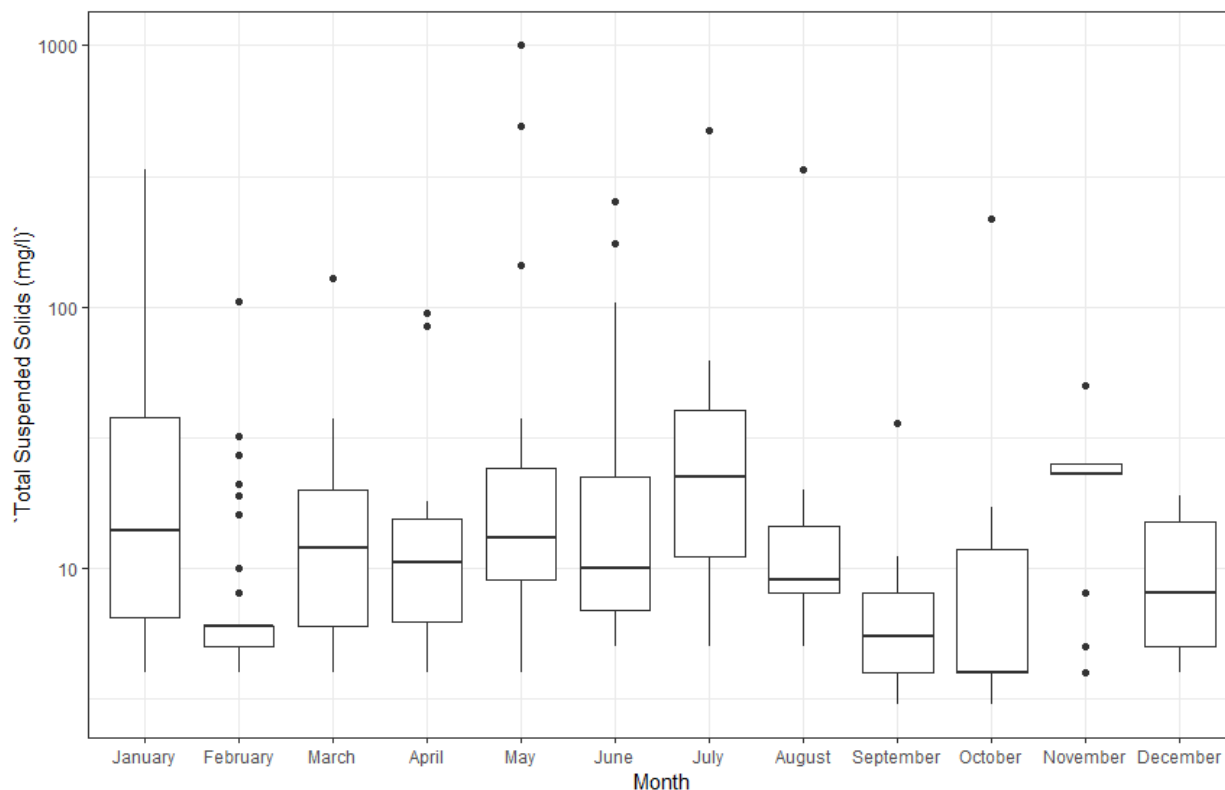


Figure 5-16. Box plot of TSS concentration measured at INSTOR_EQX-2596 by month.

5.7 Contaminant Assessment Process (CAP)

A Contaminants assessment process (CAP) report was completed for the MNWR in 1998 and updated in 2006 by the Bloomington Indiana Ecological Services Office. The most recent CAP report for MNWR can be found on the ECOS server (https://ecos.fws.gov/docs/cap/legacy/43_Muscatatuck_NWR_529609.pdf). This report notes that “the primary disturbances within the watershed are related to agriculture and rapid urban development (including industrial facilities) of the surrounding area. These activities have resulted in increased agricultural and urban run-off leading to flooding and elevated sediment, nutrient, and contaminant loads into the watershed.” The report also notes the presence of major transportation routes such as U.S. 31, U.S. 50, and I-65 and the Baltimore and Ohio Railroad, “all of which cross at least one of the 3 primary tributaries that enter the refuge.” These major transportation routes pose a potential for contamination from road runoff and accidental spills.

The report notes that the application pesticides in the watershed introduces contaminants such as organochlorines and organophosphates, which are “known to be toxic to fish and wildlife via direct exposure.” “In addition, the construction of homes and businesses has put a strain on waste water treatment facilities and septic systems which could result in nutrient and bacterial problems within the watershed”.

Additionally, the CAP report notes a 1980 train derailment, which caused 8,000–10,000 gallons of chlorobenzene to be released directly into Storm Creek.

Chlorobenzene does not generally have long term stability or persistence in the natural environment. Based on Lawrence (2006) the half-life of chlorobenzene is under anaerobic conditions is 280–580 days, although shorter under aerobic conditions. This contaminant completely mineralizes in the natural environment to benign CO₂ and chloride. Even if all of this spill would have initially remained on the MNWR, which is unlikely, and with the maximum estimated half-life, than, less than 0.1% of the initial spill would remain in 1997 and essentially none (<0.005% of the initial spill, or 0.6 gallons total over the entire refuge) would remain by 2005.

Chapter 6: Water Law

Indiana

Unlike Illinois, Indiana draws a line between surface water and groundwater: surface water¹ is public, whereas groundwater is private.² Through the state's permitting system, however, state agencies regulate both water systems. The following two sections detail the pertinent laws regarding surface and ground water systems.

I. Surface Water

Indiana applies traditional riparian rights doctrine to its surface waters, conforming to other states' standard of reasonable use. Specifically, the state legislature statutorily defined a landowner's riparian right as an "equal right to the flow of the water through his land," so long as that use does not materially injure the rights of those below him.³ The courts have found at least four rights that exist within the a riparian right, which include rights to: access to the public waterway, build a pier, accretions, reasonable use for general purposes such as boating and domestic use.⁴ In Indiana, "public waters," include naturally flowing surface waters, and they should be "put to beneficial uses to the fullest extent," and non-beneficial uses should, in fact, "be prevented."⁵ Helpfully, "beneficial use" means "the use of water for any useful and productive purpose" and, most importantly, includes "fish and wildlife" within its definition.⁶

Indiana has taken several legislative steps to protect its resources. In order to facilitate planning, the Natural Resources Commission (NRC) maintains an inventory of all state waters, which includes an assessment of whether streams are capable of supporting "instream and withdrawal uses."⁷ "Instream use," in Indiana, means the "use of water that uses surface water in place," and the statute specifically identifies fish and wildlife habitat as an instream use, among others.⁸

In addition to the inventory, state law gives the NRC power to establish minimum flows and groundwater levels, "taking into account the varying low flow characteristics of the streams

¹ Surface water in Indiana consists of lakes and streams. 14-25-1-2. "Diffused water" that falls on or pools on private land is wholly within the ownership of the landowner. *Id.*

² Ind. Code § 14-25-1-2 (2011); *New Albany & Salem R.R. v. Peterson*, 14 Ind. 112, 114 (1860) (Indiana follows doctrine of absolute use for groundwater.). Other distinctions may be drawn as well. For example, if underground channels or streams were at issue, courts would likely apply the riparian rights doctrine, as they do for surface water. *Gagnon v. French Lick Springs Hotel Co.*, 72 N.E. 849, 851–52 (1904).

³ *Dilling v. Murray*, 6 Ind. 260, 262 (1855).

⁴ *Parkison v. McCue*, 831 N.E.2d 118, 128 (Ind. App. 2006).

⁵ Ind. Code §§ 14-25-1-1, 14-25-1-2, 14-25-1-10 (2011).

⁶ Ind. Code § 14-25-7-2 (2011) (emphasis added).

⁷ Ind. Code §§ 14-25-7-13, 14-8-2-48 (2011).

⁸ Ind. Code § 14-25-7-4 (2011).

of Indiana and *the importance of instream* and withdrawal uses.”⁹ The NRC also has the power to coordinate with federal agencies on “water resource development, conservation, and use.”¹⁰

With this authority, the NRC established procedures to govern contracting with persons requesting withdrawals or releases from reservoirs.¹¹ If a FWS-managed refuge in Indiana relies upon impounded upstream water, FWS may apply for a contract with NRC for a release like any other water user.¹² While releases for instream use for fish and wildlife may be an uncommon contract request, nothing in NRC’s regulations precludes FWS from applying. Further, a contract for a release of water would be consistent with the state’s water conservation initiatives.

In the case of freshwater lakes, the NRC may declare an emergency and issue a temporary or permanent order to stop withdrawals if the “lowering of the lake level is likely to result in significant environmental harm to the freshwater lake or to adjacent property.”¹³ Also, while the state allows riparian landowners to dam and impound lakes and streams, it requires an analysis by the NRC to ensure that the level of the lake or the flow of the stream “exceeds reasonable use at the time of impoundment,” and that the dam or impoundment retains an outlet for stream flows.¹⁴

Should disputes arise over surface water use, the NRC conducts mandatory mediation between the parties, which entails a hearing and a non-binding recommendation.¹⁵

II. Groundwater

Indiana treats groundwater as a private property right of the landowner, as opposed to its treatment of surface water, which is publicly owned.¹⁶ A landowner cannot bring an action against another groundwater user for withdrawing water to the landowner’s detriment unless the withdrawal was “deliberate or gratuitous.”¹⁷

Although the state recognizes groundwater as a private resource, the state still authorized the Indiana Department of Natural Resources (DNR), a separate government body from NRC, to regulate when it “has reason to believe it is necessary and in the public interest” to restrict groundwater use for the “economy, health, and welfare” of the state and its citizens.¹⁸ To achieve this goal, the state established a program that creates “restricted use areas,” based on necessity. Groundwater users located in a designated “restricted use area” may continue to

⁹ Ind. Code § 14-25-7-14 (2011) (emphasis added).

¹⁰ Ind. Code § 14-25-7-12(7) (2011).

¹¹ 312 Ind. Admin. Code 6.3 *et seq.* (2011).

¹² 312 Ind. Admin. Code 6.3-3-1 (2011). When reservoir operators create increased flows, however, downstream riparian-right holders do not have rights to the increased flow. Ind. Code § 14-25-1-5 (2011).

¹³ Ind. Code §§ 14-25-5-7, 14-25-5-14 (2011).

¹⁴ Ind. Code § 14-25-1-4 (2011).

¹⁵ Ind. Code § 14-25-1-8 (2011).

¹⁶ *New Albany & Salem R.R. v. Peterson*, 14 Ind. 112, 114 (1860).

¹⁷ *Wiggins v. Brazil Coal & Clay Corp.*, 452 N.E.2d 958 (Ind. 1983).

¹⁸ Ind. Code § 14-25-3-3, 14-25-3-4 (2011).

withdraw water out at the same rate, but may not exceed 100,000 gallons-per-day beyond current use at the time the property becomes “a restricted use area.”¹⁹ Withdrawals in excess of that amount require a permit, which the DNR permits or denies based on a series of criteria.²⁰ The same cap applies to new users after the DNR has designated the region a “restricted use area,” with the additional requirement that new users must report when they drill new wells.²¹

Regardless of whether a water user is located within a “restricted use area,” any facility capable of withdrawing more than 100,000 gallons per day must report to the DNR.²² The DNR may also declare a groundwater emergency when evidence indicates that continued ground water withdrawals from a significant groundwater withdrawal facility will exceed the recharge capability of the groundwater resource in that area.²³ Once the DNR declares such an emergency, it can restrict the amount of water a facility withdraws upon a reasonable belief that: (1) the facility caused the emergency, (2) the remaining water is necessary to supply potable water uses, or (3) continued withdrawals will exceed recharge capability of the groundwater resource.²⁴

Additionally, like surface water, the NRC still retains authority to establish minimum groundwater levels in aquifers to determine at which point “withdrawals would be significantly harmful to the water resource of the area.”²⁵ To date, however, NRC has only exercised its authority to establish a contract system for reservoir impoundment (discussed above), and no action has been taken to permit groundwater withdrawals.²⁶

The contract system established in Indiana may provide FWS with an affirmative means of securing instream rights to water. Further, the state has enabled itself to take control of its water resources when shortages occur, halting withdrawals if need be.

¹⁹ Ind. Code § 14-25-3-6 (2011).

²⁰ *Id.*

²¹ *Id.*

²² Ind. Code § 14-25-7-15 (2011).

²³ Ind. Code § 14-25-4-10 (2011).

²⁴ Ind. Code § 14-25-4-12 (2011).

²⁵ Ind. Code § 14-25-7-14 (2011).

²⁶ 312 Ind. Admin. Code 6.3 *et seq.* (2011).

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Appendix A: Threats and Needs Table

Table A1. Threats included in the online WRIA application.

Title	Description	Threat Type	Threat Cause
Limited Source Water	Richart Lake is the primary water source for the managed moist soil units M1 through M4. This lake is only 90 acers in size and has a small watershed. Water flows from Richart lake to M1, then into M2, into M3, and finally into M4. Richart Lake is fed only by ephemeral streams and there can be insufficient water during dry years to fill M3 and M4. (i.e. Filling M4 can take weeks).	Insufficient Surface Water	Inefficient, Inadequate, or Damaged Water Management Infrastructure
Limited Source Water	Richart Lake is the primary water source for the managed moist soil units M1 through M4. This lake is only 90 acers in size and has a small watershed. Richart Lake is fed only by ephemeral streams and there can be insufficient water during dry years to fill M3 and M4. (i.e. Filling M4 can take weeks). This indicates that the current management strategy of the refuge may not be very resilient to climate variations.	Insufficient Surface Water	Increase in Drought Frequency/Severity
Beaver dams	Mutton and Storm Creeks have extensive beaver activity. Removing dams is labor intensive and dangerous activity for refuge staff. In the forested areas along these creeks, beaver activity will likely be a persistent and perennial occurrence. Also, dead timber in Moss lake is the source of substantial amounts of debris in Mutton Creek causing log jams, which further contribute to the impediment of flow.	Compromised Water Management Capability	Wildlife Sources
Flow Impediments	The impediments to flow along Storm and Mutton Creek ditches from beaver activity and aggradations has caused more frequent overbank flooding, which could damage current infrastructure. This is especially the case along Storm Creek where management units are adjacent to the Storm Creek ditch and restrict the natural meandering of the stream channel.	Compromised Water Management Capability	Inefficient, Inadequate, or Damaged Water Management Infrastructure
Flooding from Flow Impediments	Impediments to flow has resulted in persistent flooding in some areas of the refuge such as the Muscatatuck Seep Spring Research Natural Area, which is a rare ecological habitat in the state of Indiana, as well as moist soil unit M6 resulting in increased invasive cattails in M6.	Loss/Alteration of Wetland Habitat	Inefficient, Inadequate, or Damaged Water Management Infrastructure
Increased flows	Long-term trends in climate and nearby stream gauging indicate an increase in the amount of water entering the refuge.	Excess Surface Water	Change in Frequency/Severity of Extreme Precipitation Events

Table A1. Threats included in the online WRIA application.

Title	Description	Threat Type	Threat Cause
Sedimentation	The surface waters flowing into the MNWR receive high sediment loads, which has resulted in siltation and aggradation along Storm Creek and Mutton Creek ditches. Aggradation could further inhibit flow through these ditches, reducing their ability to convey water as designed. High sediment loads could also cause aggradation in impoundments and management units on the MNWR.	Sedimentation	Agricultural Runoff
Nutrient Loads	The refuge receives high nutrient loads, with total phosphorus concentration often exceeding the EPA recommendations for Eco-Region VI in the lakes and streams of the refuge. This is a result of non-point source agricultural runoff and point source pollution from urban runoff and potentially from sewage outfall in upstream residential developments.	Nutrient Pollution	Agricultural Runoff
HABs	High nutrient levels in Richart, Stanfield, and Moss Lake cause water quality issues in these lakes including algal blooms in Richart and Stanfield lakes, and low dissolved oxygen, especially in Moss Lake. Harmful algal blooms can produce toxic chemicals, which can be a potential threat to pets and wildlife. Low dissolved oxygen levels can also result in fish kills in lakes, although fish kills have not been observed in Richart and Stanfield Lake.	Low dissolved oxygen	Agricultural Runoff
E.Coli Impairment	Mutton Creek within the MNWR boundary is listed as a 303(d) impaired water body for E. Coli. This may suggest potential sewage discharge into this watershed, possibly from sewerage overflow during storm events in upstream residential developments on Mutton Creek.	Pathogens	Urban Development
303(d) impaired source water	All of the source water entering MNWR is listed as 303(d) impaired by IDEM. The degree to which source waters are impaired points to potential chronic water quality issues across the refuge, potentially exacerbated by impounding these waters.	Other Contaminants/ Altered Water Chemistry	Urban Runoff

Table A2. Needs included in the for the online WRIA Application

Title	Description	Level 1 Need	Level 2 Need
Assessment of source water quantity	Working together with the regional water resources branch, the hydrology of the Richart Lake and the upstream watershed could be assessed to understand best management practices of this lake under various meteorological scenarios, to have sufficient water for moist soil units under dry conditions. In particular, the available volume of water in Richart Lake and other lakes could be determined via bathymetric surveys and compared to the volume of water required by the moist soil units and the volume of inputs from the intermittent streams in the watershed.	Modeling / Research / Assessment	Hydrologic Modeling
Assessment of current infrastructure	Assessing the functioning of the current infrastructure and planning any potential future changes to refuge infrastructure or management requires a baseline understanding of the system hydrology. Working together with the regional water resources branch, the timing and magnitude of discharge through Storm Creek and Mutton Creek could be measured in the field and compared to the conveyance capacity of the current infrastructure.	Monitoring / Measurement	Water supply / quantity monitoring
Hydrological investigation of Seep Spring Area	The groundwater and hydrology of the Seep Spring Research and Natural Area should be monitored to assess the hydrological vulnerability of this rare ecological area. Also, the connection between the hydrology this area and other hydrological features such as Mutton Creek should be investigated to reduce flooding issues in this area.	Monitoring / Measurement	Water supply / quantity monitoring
Consider water management future goals and costs	Issues with flooding and associated damage, aging ditches and infrastructure, beaver dams, and sedimentation can interfere with the proper management of units on the refuge. Addressing these issues will likely require continued maintenance (e.g. beaver dam removal, flood damage repairs, dredging, etc.) and/or increased infrastructure (e.g. improved access roads along the creek channels or equipment like an aquatic excavator, enhanced levees along active management units, etc.). Alternatively, there could be a focus on restoring the natural hydrological functioning on the refuge, which would include restoring natural stream meanders, deconstructing levees to improve flood plain connectivity, constructing low water crossings at roads upstream of Moss Lake, etc. This approach has already been taken in a number of areas of the refuge including the southern management units, and at Mini Marsh, which have been allowed to revert to more natural hydrological fluctuations. With this approach, beaver activity may be less of an issue, and if well designed, sediment balance, flood issues and maintenance costs would be improved. Regional water resource branch staff and other experts could be enlisted to explore options.	Water Supply / Flooding	Create / Update Water Management Plan

Table A2. Needs included in the for the online WRIA Application

Title	Description	Level 1 Need	Level 2 Need
Improve ments to water Infrastruc ture	Issues with flooding and associated damage, aging ditches and infrastructure, beaver dams, and sedimentation can interfere with the proper management of units on the refuge. Addressing these issues will likely require continued maintenance (e.g. beaver dam removal, flood damage repairs, dredging, etc.) and/or increased infrastructure (e.g. improved access roads along the creek channels or equipment like an aquatic excavator, enhanced levees along active management units, etc.). Alternatively, there could be a focus on restoring the natural hydrological functioning on the refuge, which would include restoring natural stream meanders, deconstructing levees to improve flood plain connectivity, constructing low water crossings at roads upstream of Moss Lake, etc. This approach has already been taken in a number of areas of the refuge including the southern management units, and at Mini Marsh, which have been allowed to revert to more natural hydrological fluctuations. With this approach, beaver activity may be less of an issue, and if well designed, sediment balance, flood issues and maintenance costs would be improved. Regional water resource branch staff and other experts could be enlisted to explore options.	Water Supply / Flooding	Reduce Flooding Impacts
Determin e sediment loads and sources	In order to understand and mitigate the high sediment loads received by the refuge, initial investigation is needed to better characterize the sediment loads, source, and amount of legacy sediment in the refuge water bodies.	Monitoring / Measurem ent	Suspended Sediment Monitoring / Measuremen t
Investigat e upstream Sewage overflows	There is a need to characterize issues with the potential point source sewage overflows upstream of the refuge. By working together with residential developments, landowners, and municipalities, issues with upstream point source pollutants should be identified, quantified, and documented.	Modeling / Research / Assessmen t	Water Quality Concentratio n / Loading Assessment
Mitigate upstream Sewage overflows	By working together with residential developments, landowners, and municipalities, issues with upstream point source pollutants should be identified, quantified, and documented. Then, through education and collaboration, these issues could then be addressed.	Water Quality Mitigation / Habitat Improveme nt	Reduce point-source pollution

Table A2. Needs included in the for the online WRIA Application

Title	Description	Level 1 Need	Level 2 Need
Improve source water quality	By working with local landowners, and other organizations like local soil and water conservation districts, and the NRCS, water quality issues including sediment loads and nutrients within the source watersheds of MNWR could be discussed and improved. In this case, reaching out to the local landowners and others may be feasible because Storm Creek and Mutton Creek have a relatively small source watersheds. Further, recreational opportunities provided by the refuge in close proximity to Seymore, IN and other towns may help encourage a local sense of ownership for water quality issues of the source watersheds.	Coordination / Support	Build / Strengthen / Expand Watershed Partnerships
Improve source water quality-reduce non-point source pollution	By working with local landowners, and other organizations like local soil and water conservation districts, and the NRCS, water quality issues including sediment loads and nutrients within the source watersheds of MNWR could be discussed and improved.	Water Quality Mitigation / Habitat Improvement	Reduce non-point source pollution

Appendix B: NPDES permits in the RHI

Table B-1. Active NPDES permit sites in the Mutton Creek and Storm Creek Watersheds upstream of MNWR.

NPDES ID	FACILITY NAME	COUNTY	LATITUDE/ Longitude	EXPIRED DATE
INRM00879	AISIN U.S.A. MANUFACTURING, INC.	JACKSON	Latitude: 38.96938 Longitude: -85.86143	JUN-28-2019
INRM02340	AISIN USA MANUFACTURING INCORPORATED	JACKSON	Latitude: 38.97061 Longitude: -85.87161	MAY-28-2023
INR10I755	BURKHART CROSSING	JACKSON	Latitude: 38.97856 Longitude: -85.87576	JUL-28-2019
INRM01851	CEREPLAST INC	JACKSON COUNTY	Latitude: 38.97178 Longitude: -85.86196	MAR-17-2020
INRM00922	CUMMINS INDUSTRIAL CENTER	JACKSON	Latitude: 38.96283 Longitude: -85.87839	APR-10-2020
INR10M386	CUMMINS SEP - SEYMOUR RECEIVING EXPANSION	JACKSON	Latitude: 38.9622 Longitude: -85.8739	JUL-22-2021
INR10P028	DUKE ENERGY SEYMOUR, IN	JACKSON	Latitude: 38.95815 Longitude: -85.8631	JUN-07-2022
ING080247	FORMER SEYMOUR MARATHON HEN HOUSE	JACKSON	Latitude: 38.95877 Longitude: -85.83548	FEB-29-2012
INRA01606	FREDDYS FROZEN CUSTARD	JACKSON	Latitude: 38.95798 Longitude: -85.85683	JUN-17-2023
INR10J470	GOLDEN ENDEAVORS, KILLION PROPERTY - BUILDING EXPANSION	JACKSON	Latitude: 38.97192 Longitude: -85.86241	DEC-10-2019
INRA01309	I 65 SEYMOUR FILL SITE 2	JACKSON	Latitude: 38.995648 Longitude: -85.834825	MAY-20-2023
INRA01482	I65 PROJECT LEAD DES 0501212 IN DOT DES 1601732, 1601732, 1592590, 1592592	JACKSON	Latitude: 38.968889 Longitude: -85.843611	MAY-15-2023
INR10L085	INDOT WEIGH STATION REHABILITATION	JACKSON	Latitude: 38.96135 Longitude: -85.84332	OCT-19-2020
INRM01239	JACKSON COUNTY TRANSFER & RECYCLING STATION	JACKSON	Latitude: 38.95032 Longitude: -85.842986	FEB-25-2019
INRA02061	JACKSON COUNTY WATER UTILITY INC WATERWORKS IMPROVEMENTS 2018 WATER DISTRIBUTIO	JACKSON	Latitude: 38.873333 Longitude: -85.781389	AUG-16-2023
ING340019	LA GLORIA OIL & GAS CO	JACKSON	Latitude: 39.0235 Longitude: -85.836583	OCT-31-2020
INR10L191	MURPHY OIL USA FUEL STATION	JACKSON	Latitude: 38.95815 Longitude: -85.8644	NOV-23-2020
INR10N912	O & K AMERICAN CORP.- BUILDING EXPANSION SEYMOUR, INDIANA	JACKSON	Latitude: 38.96921 Longitude: -85.86448	MAY-18-2022
INR10P257	POMP TIRE SITE PLAN SEYMOUR IN	JACKSON	Latitude: 38.9458 Longitude: -85.8419	JUL-13-2022
INRM00375	SEYMOUR TUBING, INC.	JACKSON	Latitude: 38.96585 Longitude: -85.86828	MAR-06-2021
INR10I394	SITE IMPROVEMENTS FOR A COMMERCIAL DEVELOPMENT FOR ROYALTY COMPANIES INC	JACKSON	Latitude: 38.96001 Longitude: -85.86006	MAY-20-2019
INR10K699	TDK DEVELOPMENT	JACKSON	Latitude: 38.95876 Longitude: -85.84853	AUG-21-2020
INR10L410	TDK DEVELOPMENT INC WAREHOUSE	JACKSON	Latitude: 38.95876 Longitude: -85.84853	FEB-01-2021
IN0057789	TRAVELCENTERS OF AMERICA - SEYMOUR	JACKSON	Latitude: 38.95829 Longitude: -85.8368	FEB-28-2021
INR10P373	US 50 / SANITARY SEWER INTERCEPTOR PROJECT	JACKSON	Latitude: 38.9328 Longitude: -85.8478	JUL-27-2022

Table B-2. Active NPDES permit sites in the Vernon Fork Muscatatuck River upstream of the MNWR

NPDES ID	FACILITY NAME	COUNTY	LATITUDE/ LONGITUDE	PERMIT EXPIRED DATE
INR10P335	2016 WASTEWATER COLLECTION IMPROVEMENTS	JENNINGS	Latitude: 39.0242 Longitude: -85.6469	MAY-22-2022
INRM01973	ATMOSPHERE ANNEALING, LLC	JENNINGS	Latitude: 39.01821 Longitude: -85.63186	JUL-20-2021
INRM02200	ATMOSPHERE ANNEALING, LLC	JENNINGS	Latitude: 39.01821 Longitude: -85.63186	APR-20-2022
INRA00600	AUTUMN TRACE ASSISTED LIVING TRI MAK BUILDING SERVICES	JENNINGS	Latitude: 39.011111 Longitude: -85.645833	DEC-04-2022
INR10N666	BURNT PINES WATER SYSTEM IMPROVEMENTS PROJECT	JENNINGS	Latitude: 38.9853 Longitude: -85.6586	APR-13-2022
INRA01151	CAMPBELL TOWNSHIP VOLUNTEER FIRE DEPARTMENT NEW CONSTRUCTION	JENNINGS	Latitude: 39.028889 Longitude: -85.533056	APR-02-2023
INR10N191	CASEY'S GENERAL STORE - NORTH VERNON, IN	JENNINGS	Latitude: 39.023541 Longitude: -85.649889	JAN-05-2022
INR10N605	CITY OF NORTH VERNON STATE ROAD 3 WIDENING PROJECT NORTH OF NORTH VERNON	JENNINGS	Latitude: 39.0392 Longitude: -85.6403	APR-03-2022
INR10P418	CROSLEY LAKE DAM IMPROVEMENTS PROJECT	JENNINGS	Latitude: 38.9556 Longitude: -85.5919	AUG-03-2022
INR10K012	DAVE O'MARA CONTRACTOR'S SPOIL SITE ON CHRIS WEBER'S PROPERTY	JENNINGS	Latitude: 38.997771 Longitude: -85.631763	APR-30-2020
INR10L907	DAVE O'MARA CONTRACTORS SPOIL SITE ON NELSON PROPERTY ON CR 175 N IN NORTH VERN	JENNINGS	Latitude: 39.0094 Longitude: -85.6967	MAY-04-2021
INR10I748	DAVE O'MARA CONTRACTOR'S SPOIL STOCKPILE ON MOOSE LODGE PROPERTY	JENNINGS	Latitude: 39.0253 Longitude: -85.6428	JUL-28-2019
INRA01605	DAVE OMARA STOCKPILE AT NORTH VERNON SERVICE CENTER	JENNINGS	Latitude: 39.028406 Longitude: -85.626018	JUN-05-2023
INR10P994	DECATUR MOLD TOOL AND ENGINEERING, INC. PARKING LOT EXPANSION	JENNINGS	Latitude: 39.035 Longitude: -85.661111	NOV-06-2022
INR10J518	DOLLAR GENERAL STORE	JENNINGS	Latitude: 39.04 Longitude: -85.67	DEC-29-2019
INR10N941	DR HOUSING ROAD	JENNINGS	Latitude: 39.04728 Longitude: -85.52876	MAY-22-2022
INRM01730	EBBING AUTO PARTS	JENNINGS	Latitude: 38.97683 Longitude: -85.72327	FEB-24-2019
INRM00776	EBBINGS AUTO PARTS INC	JENNINGS	Latitude: 38.976142 Longitude: -85.724059	JUL-21-2019
INRM00864	ERLER INDUSTRIES INCORPORATED	JENNINGS	Latitude: 39.00577 Longitude: -85.63339	JUN-28-2019
INRM02268	GT INDUSTRIES, INC.	JENNINGS COUNTY	Latitude: 39.038889 Longitude: -85.641667	SEP-10-2022
ING490100	HANSON AGGREGATES HAYDEN	JENNINGS	Latitude: 38.983611 Longitude: -85.723889	SEP-30-2020
INR10J871	HAYDEN RSD WASTEWATER TREATMENT & DISPOSAL SYSTEM	JENNINGS	Latitude: 38.9794 Longitude: -85.7428	APR-07-2020
INRM00385	HILEX POLY CO LLC	JENNINGS	Latitude: 39.013956 Longitude: -85.633334	JUN-29-2019
INR10J613	JENACRES EGG FARM EXPANSION	JENNINGS	Latitude: 39.0083 Longitude: -85.575	FEB-09-2020
INR10M597	JENACRES EGG FARM PHASE 2	JENNINGS	Latitude: 39.0083 Longitude: -85.575	AUG-25-2021
INR10L220	JENNINGS COUNTY BRIDGE NO 52 REPLACEMENT	JENNINGS	Latitude: 39.0092 Longitude: -85.5008	DEC-08-2020

Table B-2. Active NPDES permit sites in the Vernon Fork Muscatatuck River upstream of the MNWR

NPDES ID	FACILITY NAME	COUNTY	LATITUDE/ LONGITUDE	PERMIT EXPIRED DATE
INRM01553	JENNINGS COUNTY PALLETS INC	JENNINGS	Latitude: 39.032819 Longitude: -85.51499	AUG-15-2023
IN0056049	JENNINGS NORTHWEST REGIONAL UTILITY	JENNINGS	Latitude: 39.022778 Longitude: -85.698889	MAR-31-2021
INR10M775	LP INVESTMENT LLC	JENNINGS	Latitude: 39.03968 Longitude: -85.64104	SEP-20-2021
INR10K025	MAIN STREET PARKING IMPROVEMENTS	JENNINGS	Latitude: 39.00589 Longitude: -85.62574	MAY-01-2020
INRM01269	MARTINREA INDUSTRIES, INC.	JENNINGS	Latitude: 39.019609 Longitude: -85.631018	MAR-26-2023
INRM01513	METALDYNE LLC	JENNINGS	Latitude: 39.0319 Longitude: -85.640219	NOV-05-2019
INR10N530	METALDYNE PERFORMANCE GROUP ROADWAY EXTENSION	JENNINGS	Latitude: 39.0294 Longitude: -85.6383	MAR-23-2022
INR10M598	METALDYNE SINTERFORGED PRODUCTS LLC BUILDING EXPANSION	JENNINGS	Latitude: 39.0294 Longitude: -85.6383	AUG-25-2021
INR10J291	MORGAN POND	JENNINGS	Latitude: 39.0157 Longitude: -85.6518	OCT-28-2019
IN0043478	MUSCATATUCK URBAN TRAINING CTR	JENNINGS	Latitude: 39.04728 Longitude: -85.52876	JAN-31-2023
IN0062430	MUSCATATUCK URBAN TRAINING CTR	JENNINGS	Latitude: 39.04728 Longitude: -85.52876	MAY-31-2021
INRM01500	NORTH VERNON INDUSTRY CORP	JENNINGS	Latitude: 39.040352 Longitude: -85.626089	APR-21-2019
IN0004740	NORTH VERNON WATER WORKS	JENNINGS	Latitude: 39.009333 Longitude: -85.618472	DEC-31-2019
INL020451	NORTH VERNON WWTP	JENNINGS COUNTY	Latitude: 39.00494 Longitude: -85.62509	DEC-31-2020
IN0020451	NORTH VERNON WWTP	JENNINGS	Latitude: 39.00428 Longitude: -85.61323	JAN-31-2020
INR10K818	O'MARA BORROW SITE FOR US 50 BYPASS ON APSLEY PROPERTY	JENNINGS	Latitude: 39.0142 Longitude: -85.6036	SEP-11-2020
INR10N249	STEPHEN L SOLLMAN POND RENOVATION	JENNINGS	Latitude: 39.0281 Longitude: -85.6617	JAN-23-2022
INR10L511	STORAGE EXPRESS DRAINAGE	JENNINGS	Latitude: 39.0019 Longitude: -85.6347	FEB-23-2021
INRA02040	TRIPTON PARK	JENNINGS	Latitude: 39.00442 Longitude: -85.62199	AUG-16-2023
INR10P190	US 50 INTERSECTION IMPROVEMENT PROJCT 1592510	JENNINGS	Latitude: 38.98702 Longitude: -85.68116	JUN-20-2022
INR10K005	US 50 NORTH VERNON BYPASS - EAST	JENNINGS	Latitude: 39.0328 Longitude: -85.6403	APR-27-2020
IN0109703	HOLTON WWTP, TOWN OF	RIPLEY	LATITUDE: 39.0845, Longitude: -85.4104	Aug-31-2021
INR10N561	TOWN OF HOLTON STORMWATER IMPROVEMENTS	RIPLEY	LATITUDE: 39.070494, Longitude: -85.368675	MAR-24-2022
INR10P902	JENNINGS COUNTY HIGH SCHOOL SYNTHETIC TURF IMPROVEMENTS	JENNINGS	Latitude: 38.99993 Longitude: -85.64451	OCT-22-2022
INR10I822	Versailles/Holton Wesleyan Church	RIPLEY	LATITUDE: 39.0751, Longitude: -85.350915	AUG-07-2019



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